

Volatility-Blackbox Report

Generated: 2026-02-27 10:55:22

Data: S&P 500 (^GSPC), daily, 2003-2024.

Evaluation: expanding rolling OOS with test_size=21 and step_size=21.

Models: baseline GARCH-t, pure LSTM/GRU, hybrid GARCH+LSTM/GRU, residual hybrids.

Metrics: MSE and QLIKE on daily variance forecasts.

RNN preprocessing: train-only transforms (log+standardize target for variance targets;

standardize target for residual targets; log+standardize GARCH features).

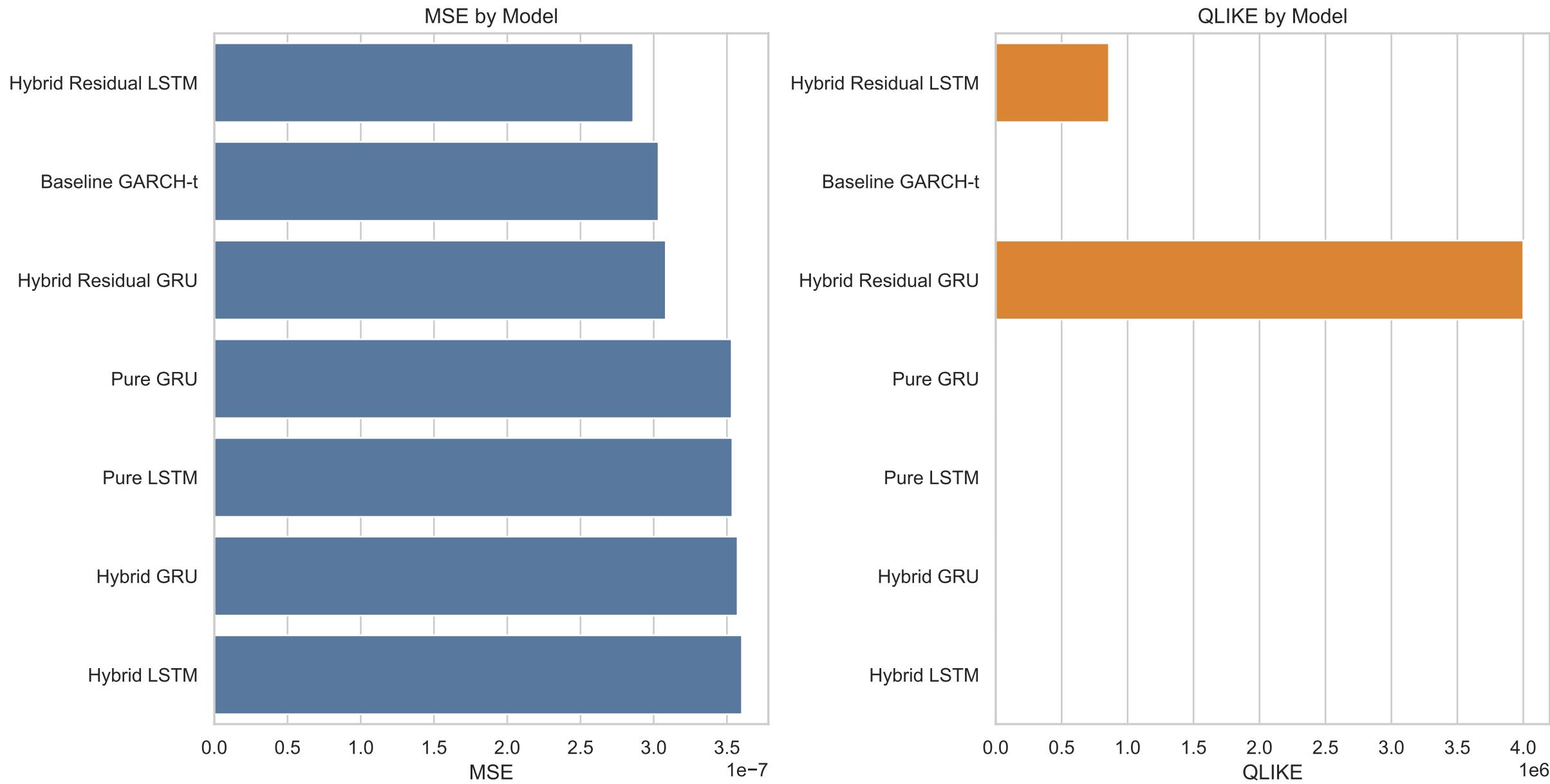
Output layer for RNNs is linear with inverse transform applied at inference.

Performance Snapshot

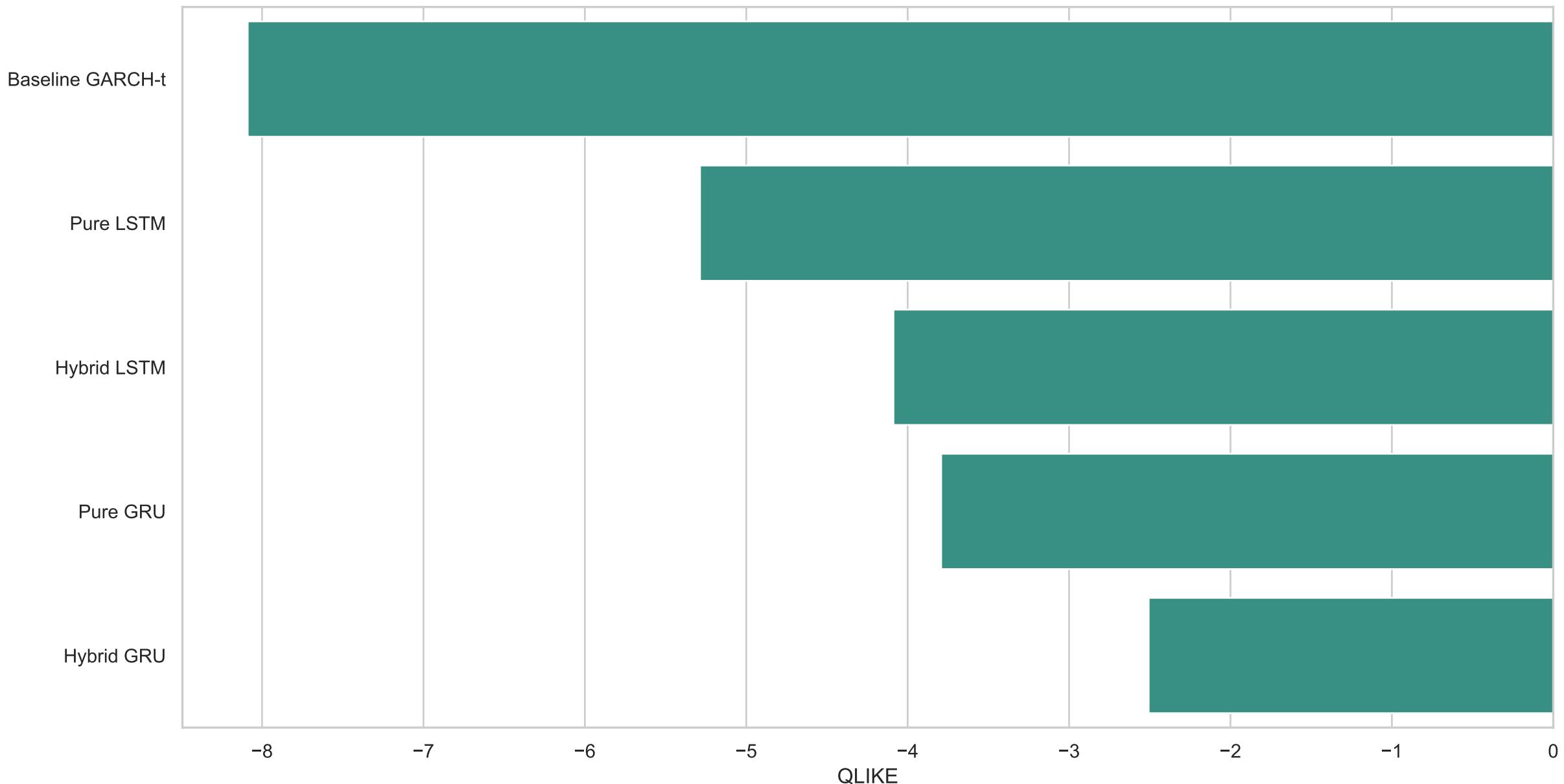
model	n_obs	mse	qlike
Hybrid Residual LSTM	4473	2.860449e-07	8.588371e+05
Baseline GARCH-t	4515	3.033150e-07	-8.088939e+00
Hybrid Residual GRU	4473	3.082436e-07	4.000313e+06
Pure GRU	4515	3.532426e-07	-3.792360e+00
Pure LSTM	4515	3.537221e-07	-5.286387e+00
Hybrid GRU	4473	3.572742e-07	-2.506646e+00
Hybrid LSTM	4473	3.602508e-07	-4.088043e+00

Model Performance: MSE and QLIKE

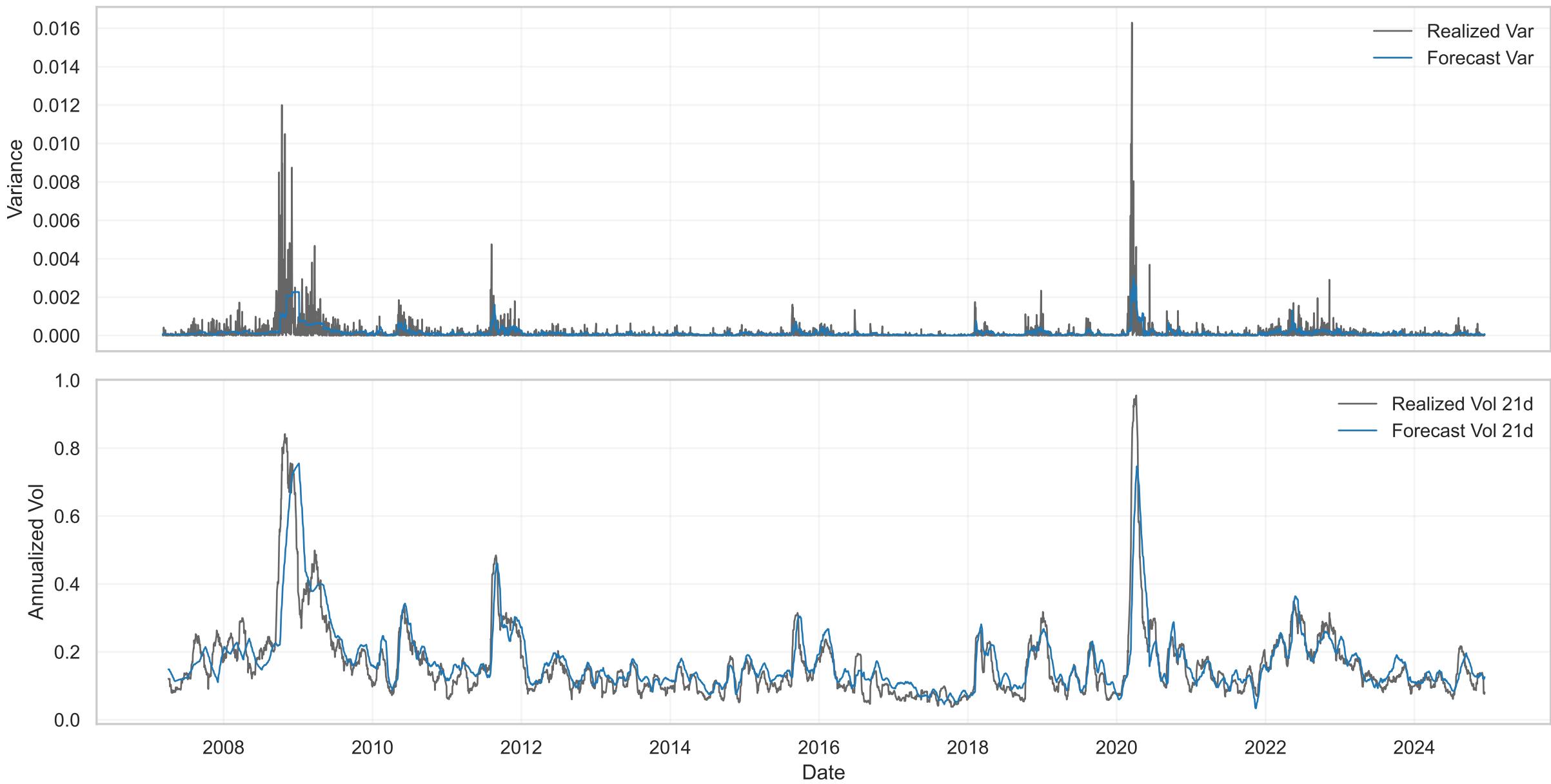
Lower is better for both metrics



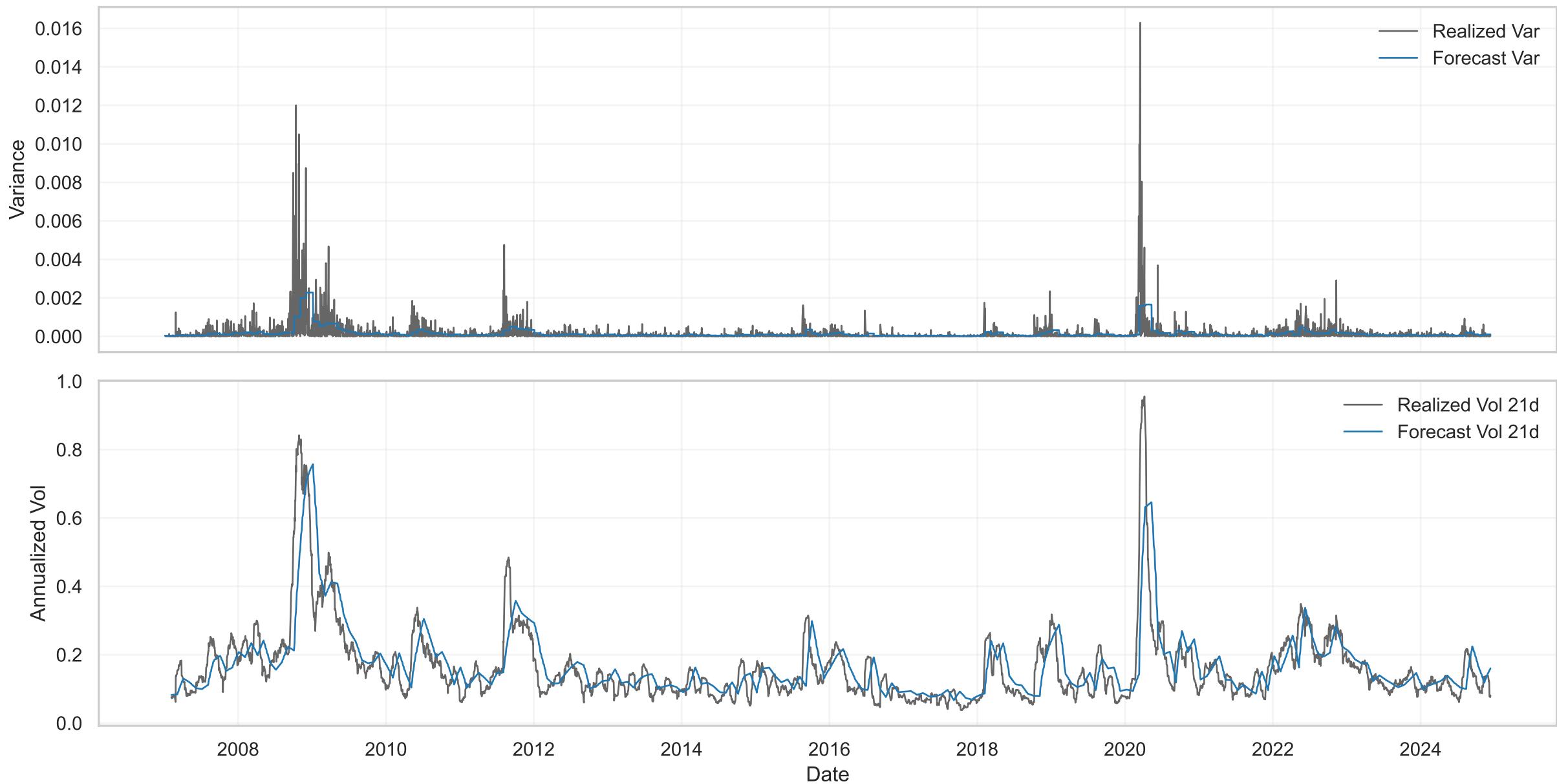
QLIKE by Model (Residual-Hybrid Excluded)



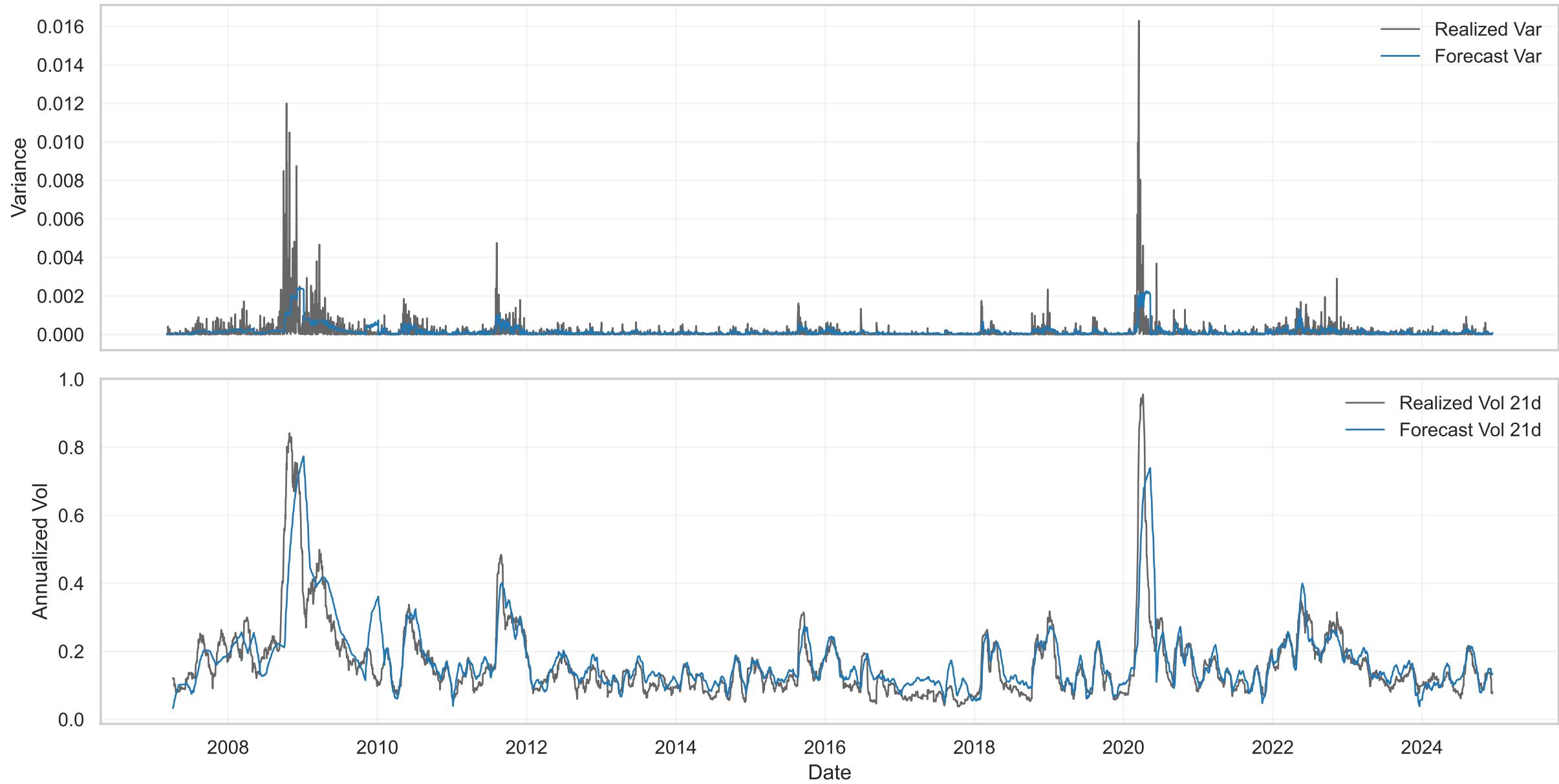
Hybrid Residual LSTM: Forecast vs Realized



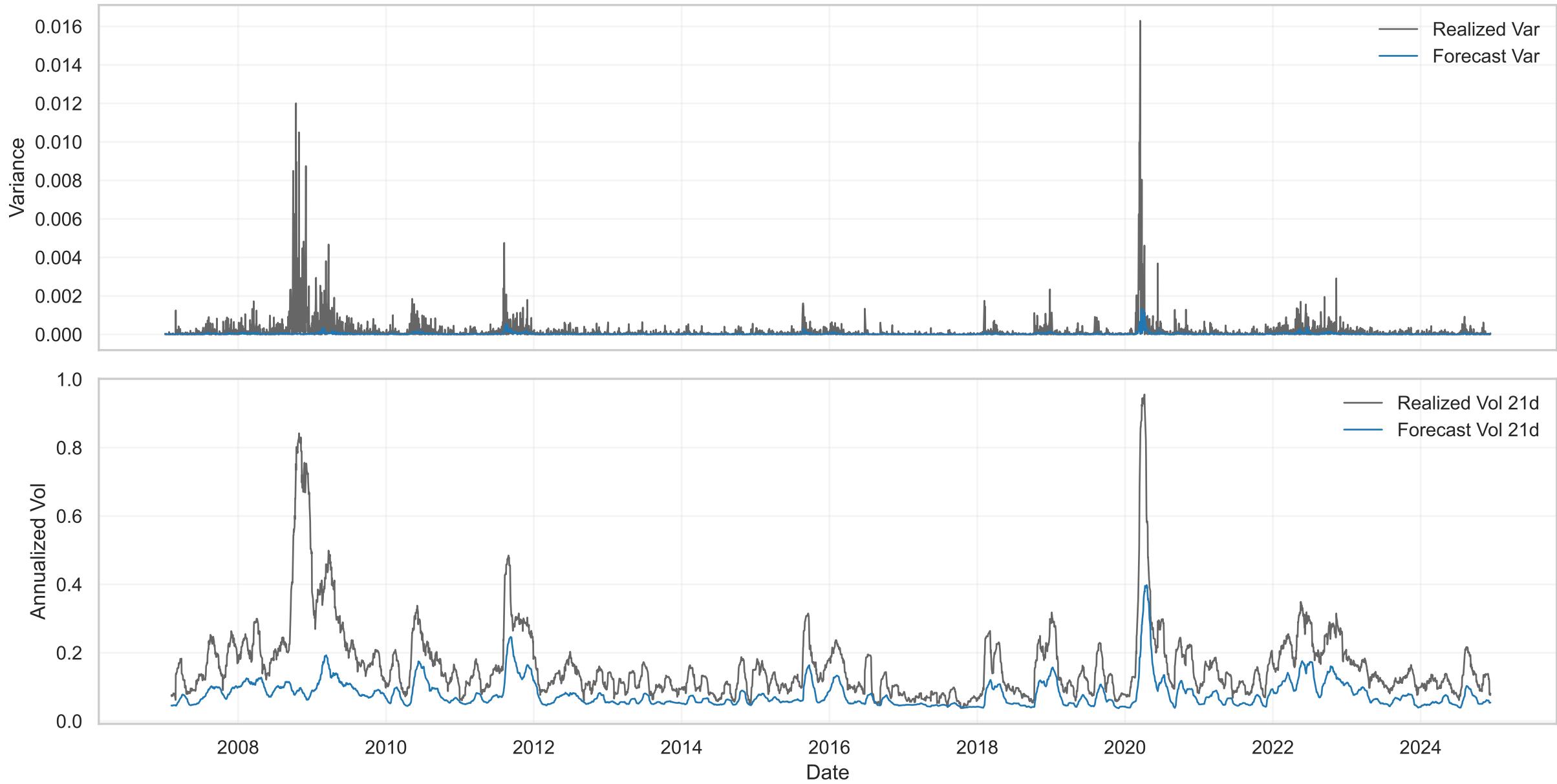
Baseline GARCH-t: Forecast vs Realized



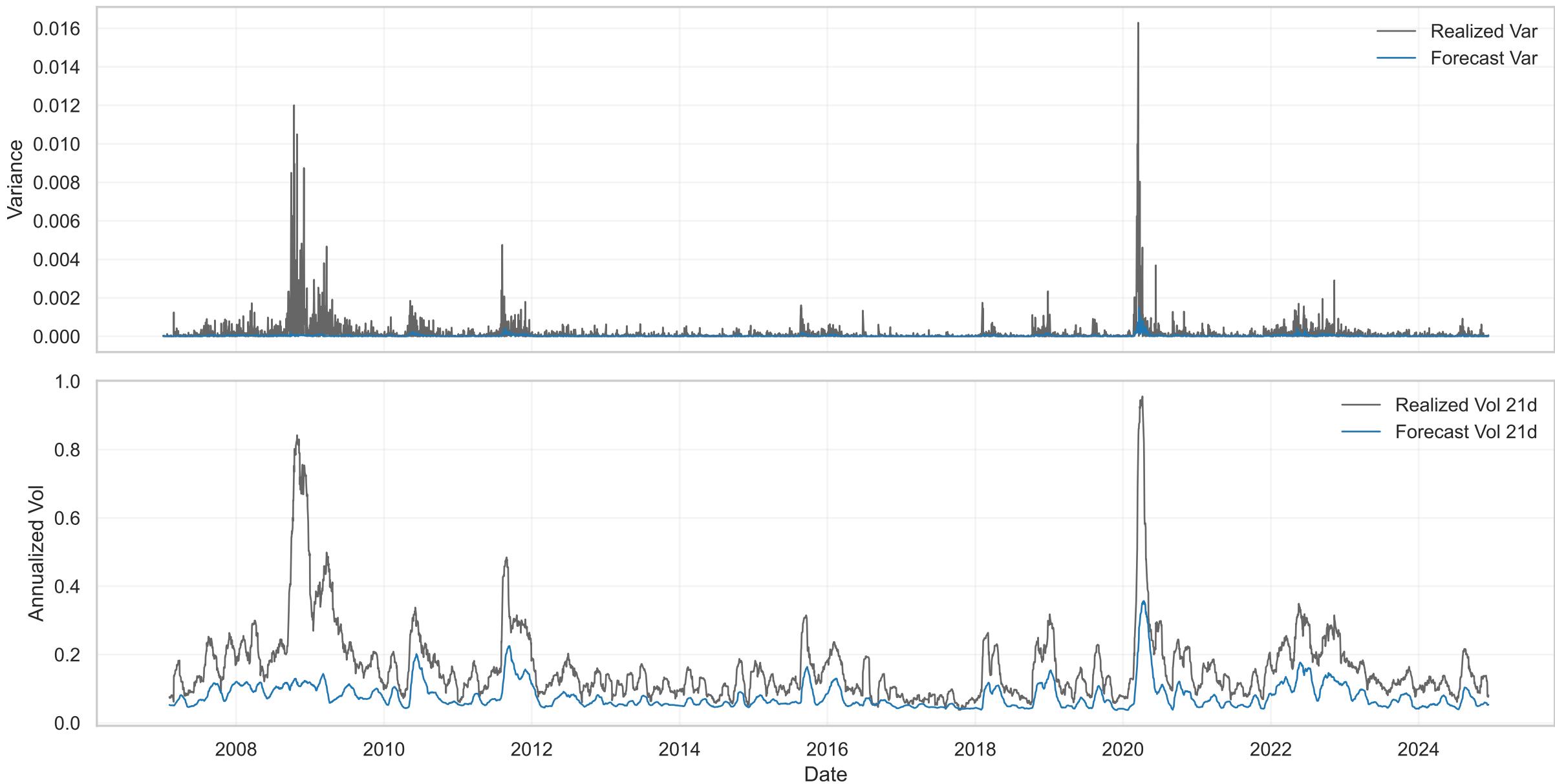
Hybrid Residual GRU: Forecast vs Realized



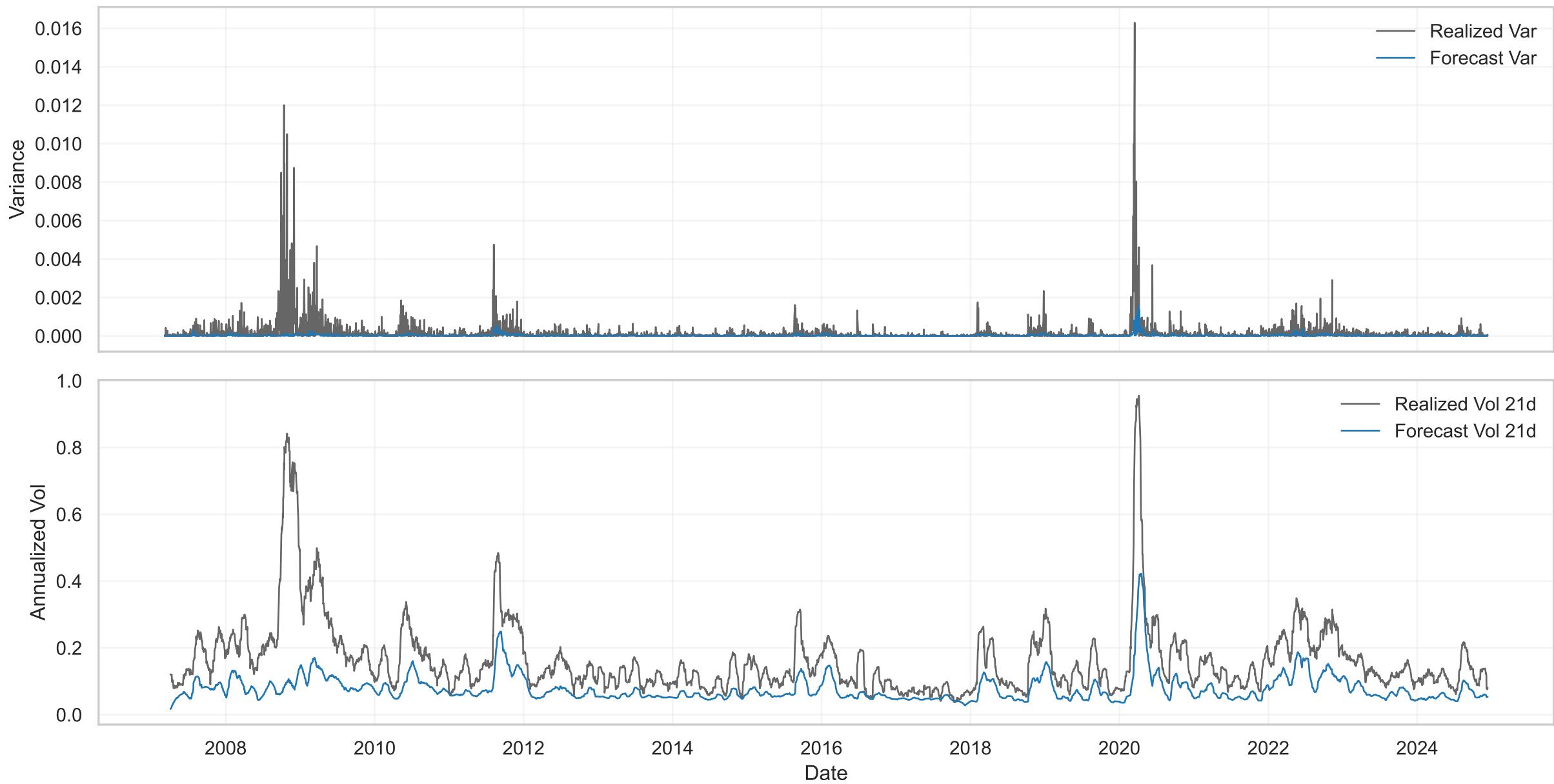
Pure GRU: Forecast vs Realized



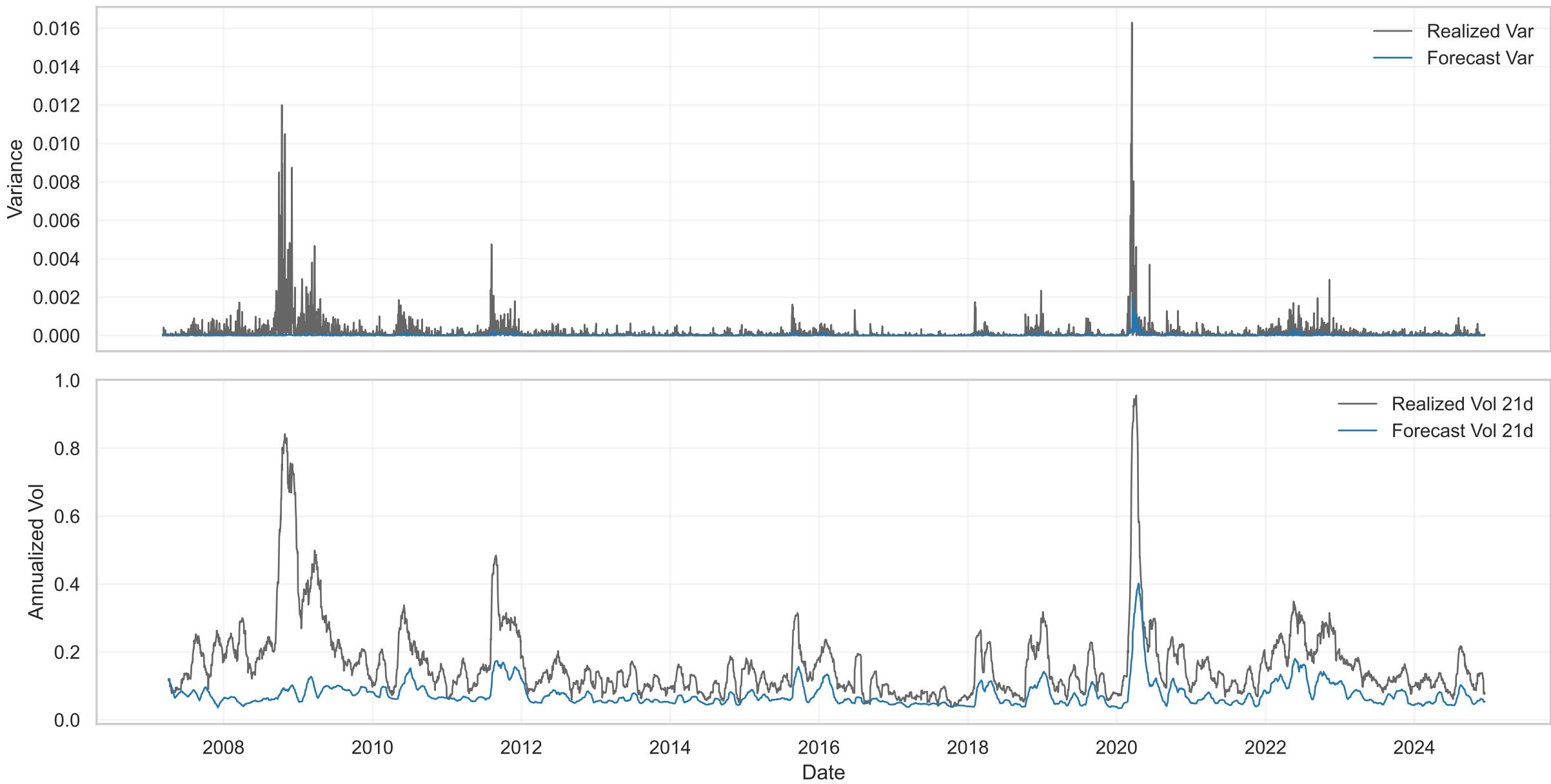
Pure LSTM: Forecast vs Realized



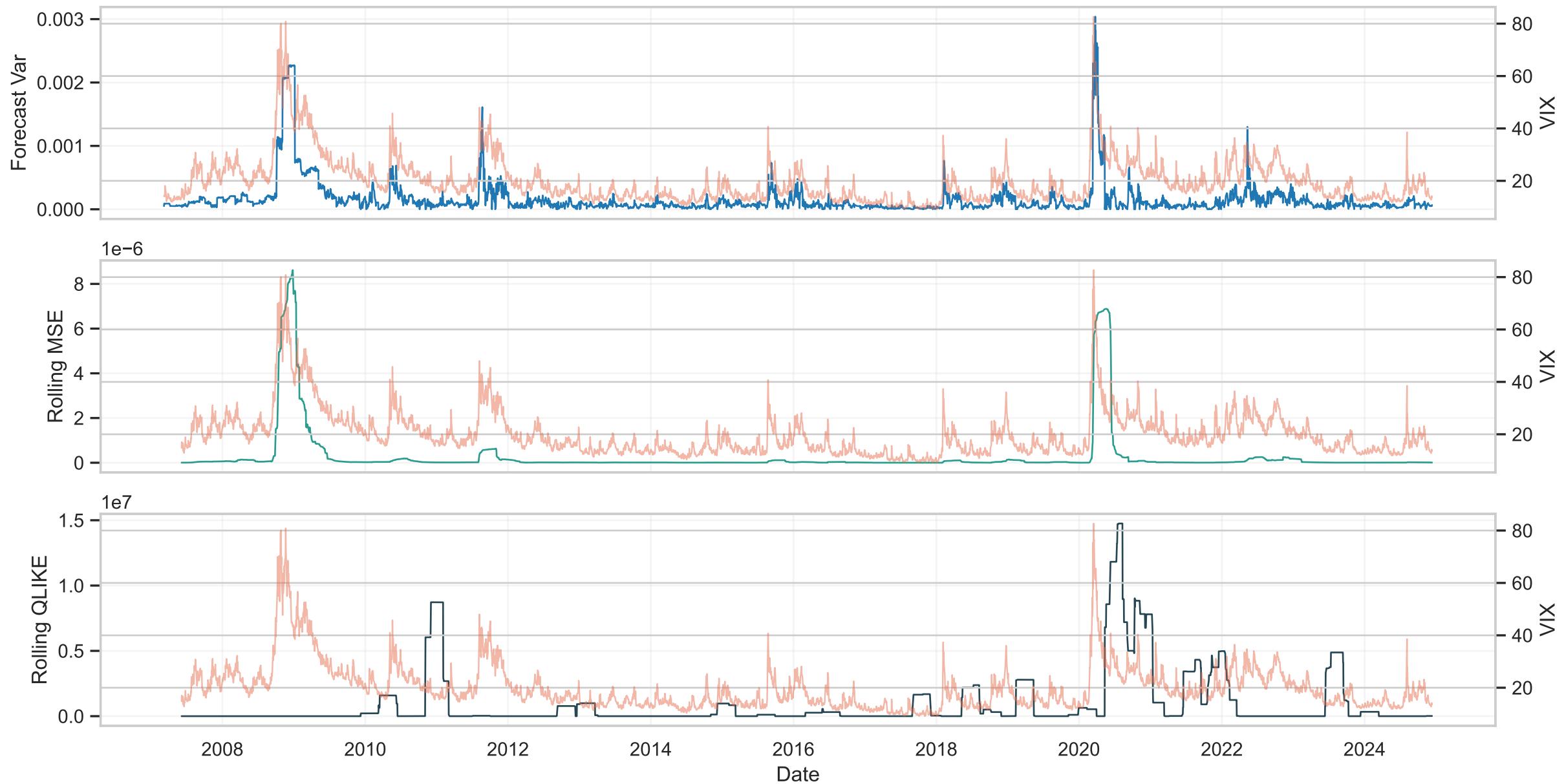
Hybrid GRU: Forecast vs Realized



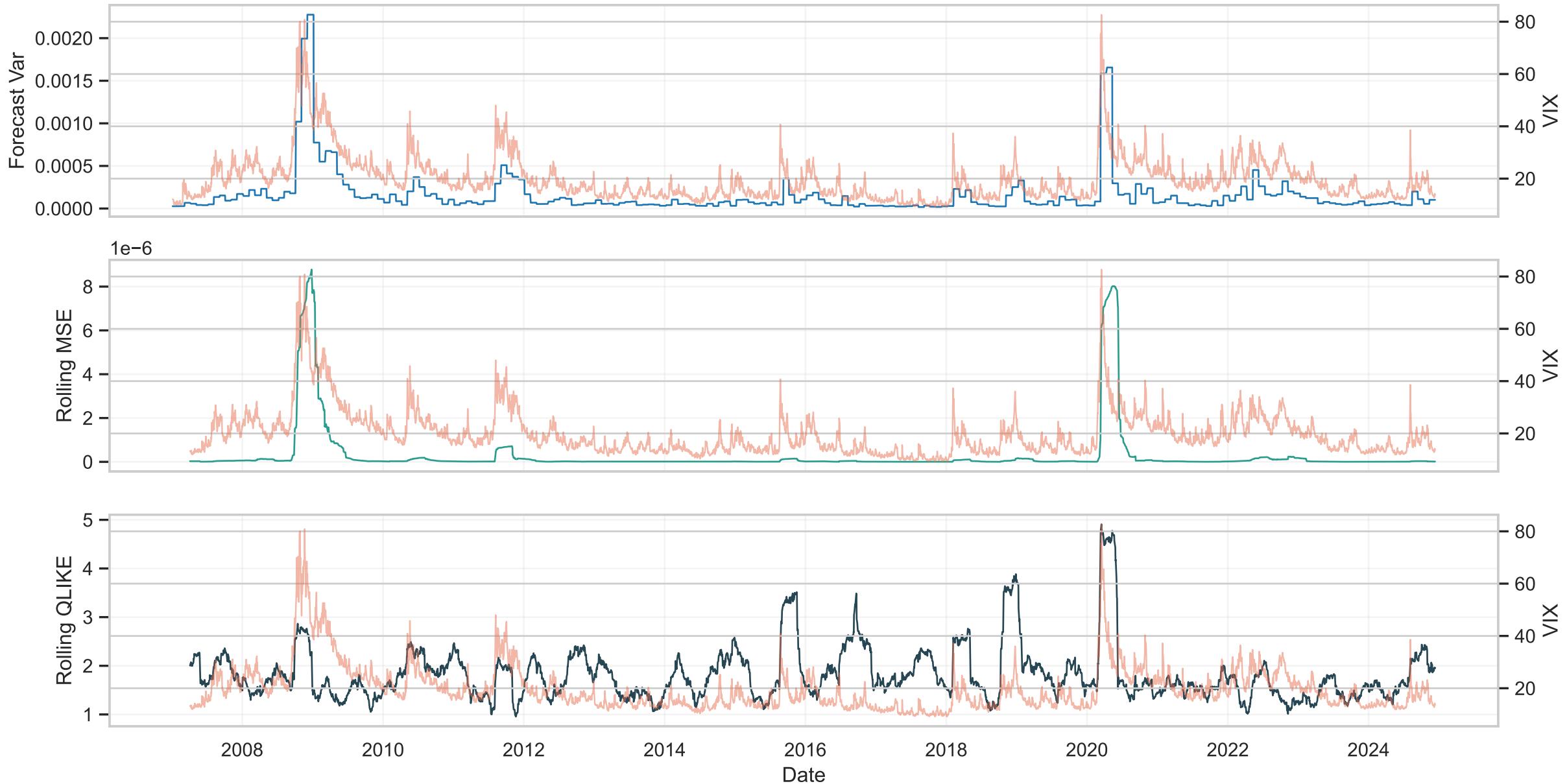
Hybrid LSTM: Forecast vs Realized



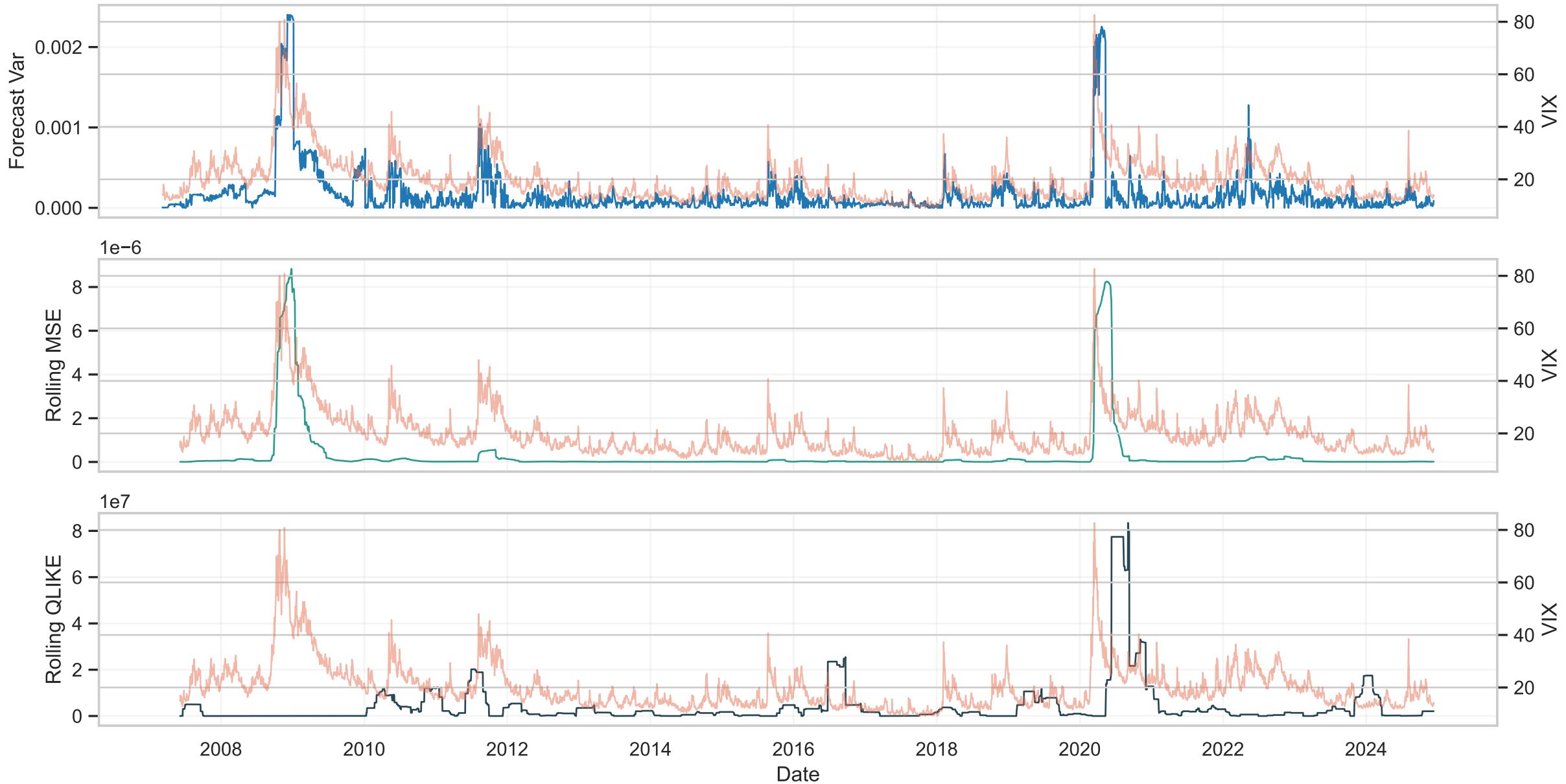
Hybrid Residual LSTM: VIX and Forecast/Error Diagnostics



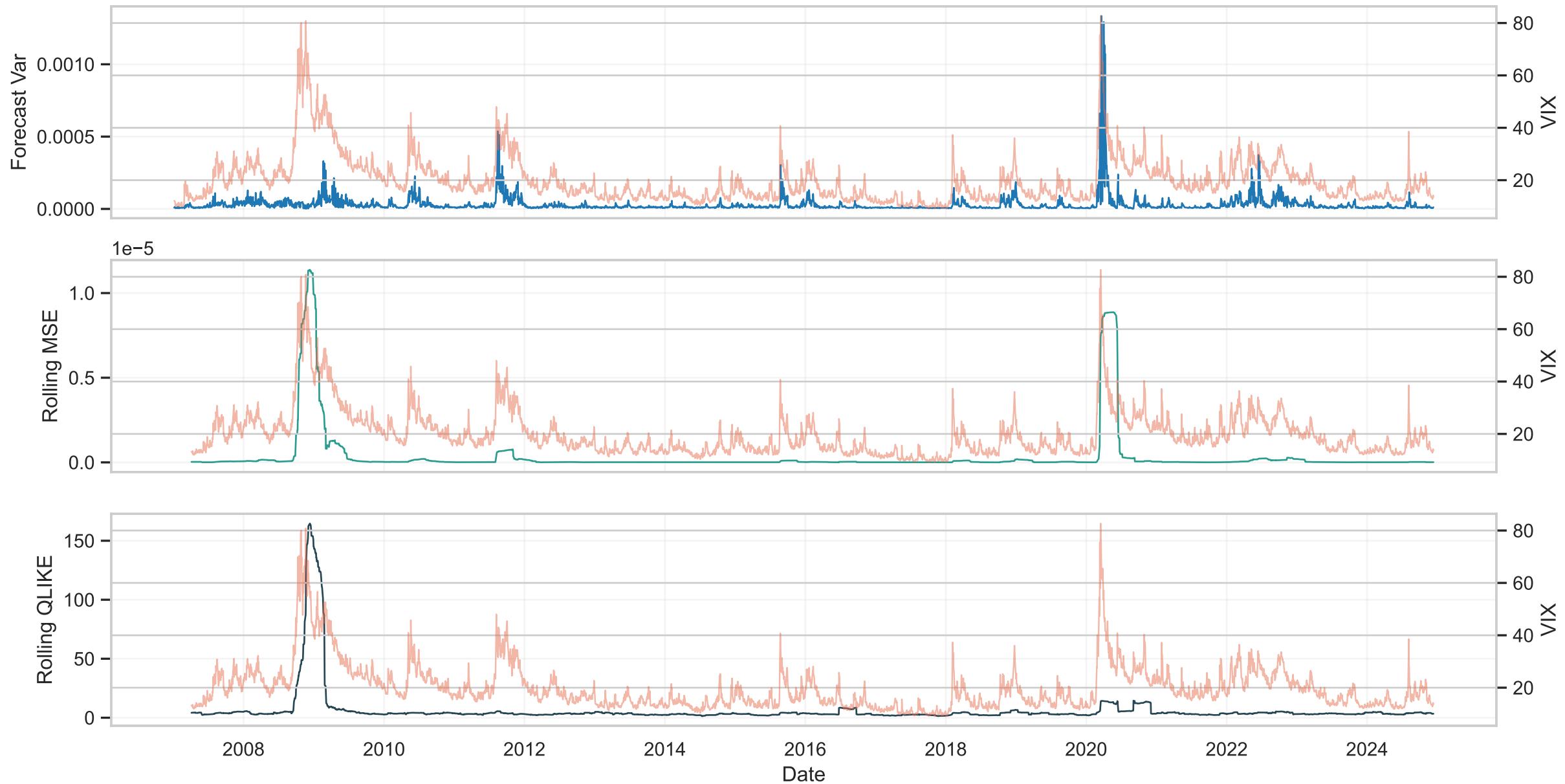
Baseline GARCH-t: VIX and Forecast/Error Diagnostics



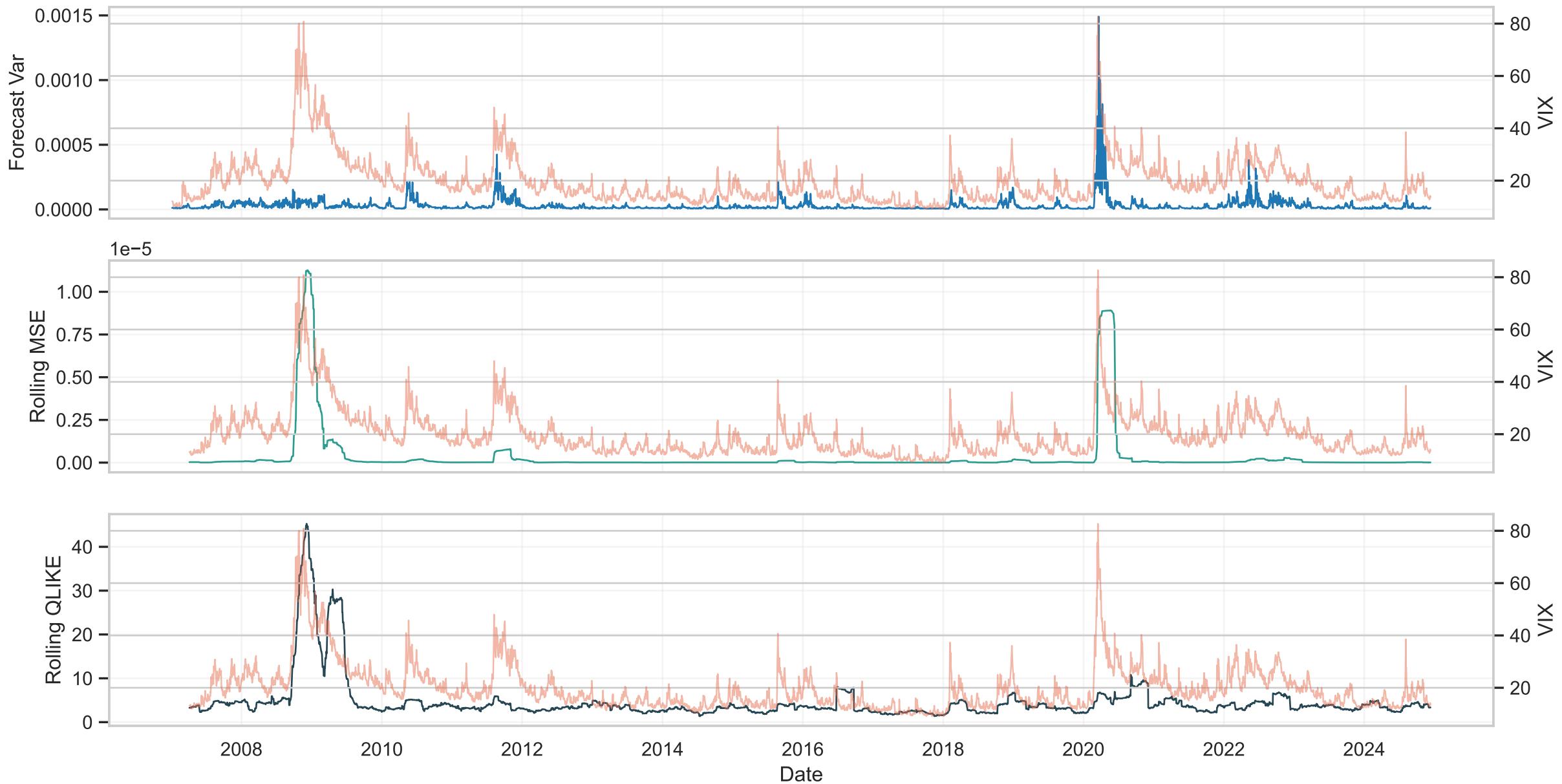
Hybrid Residual GRU: VIX and Forecast/Error Diagnostics



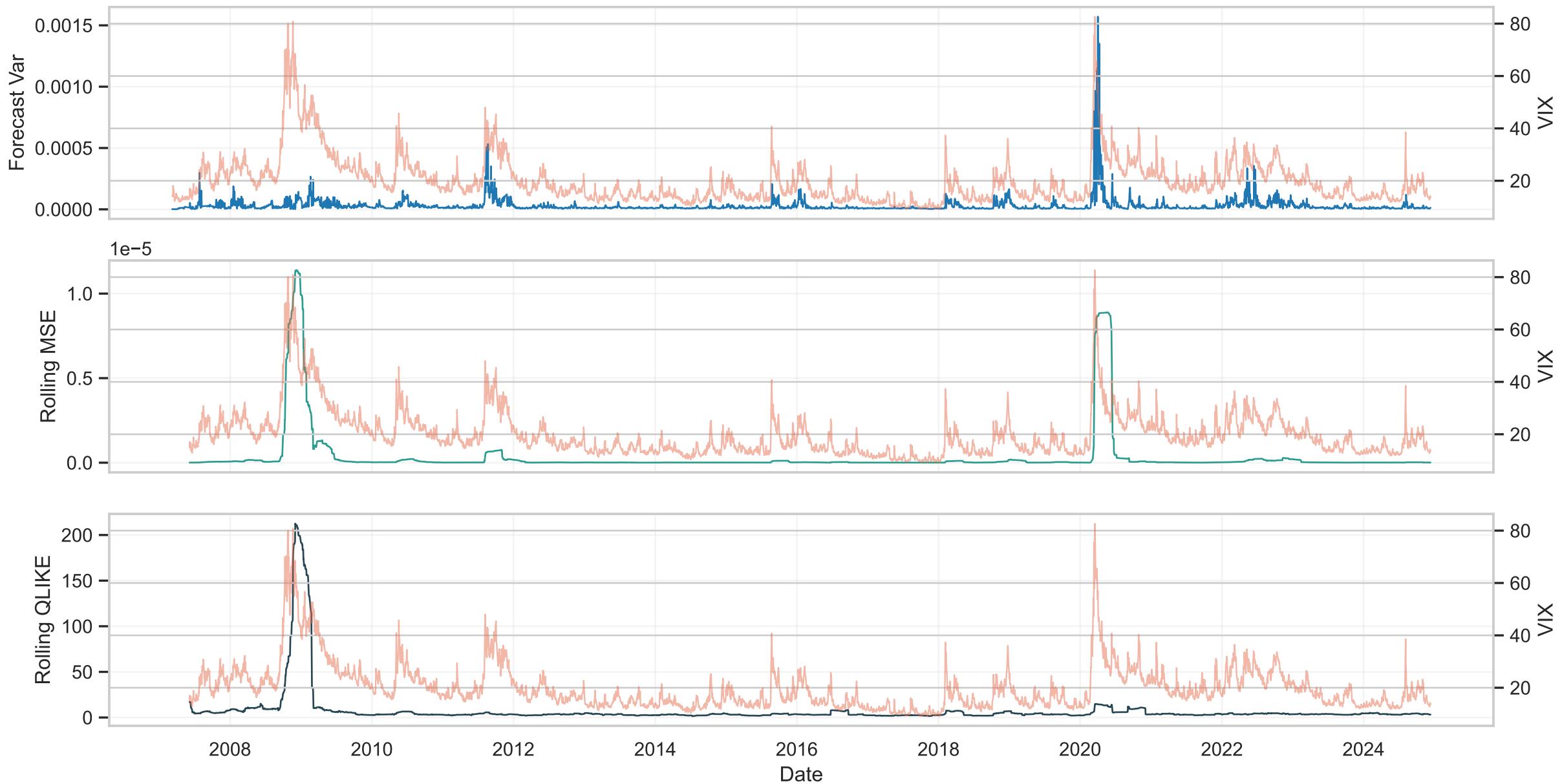
Pure GRU: VIX and Forecast/Error Diagnostics



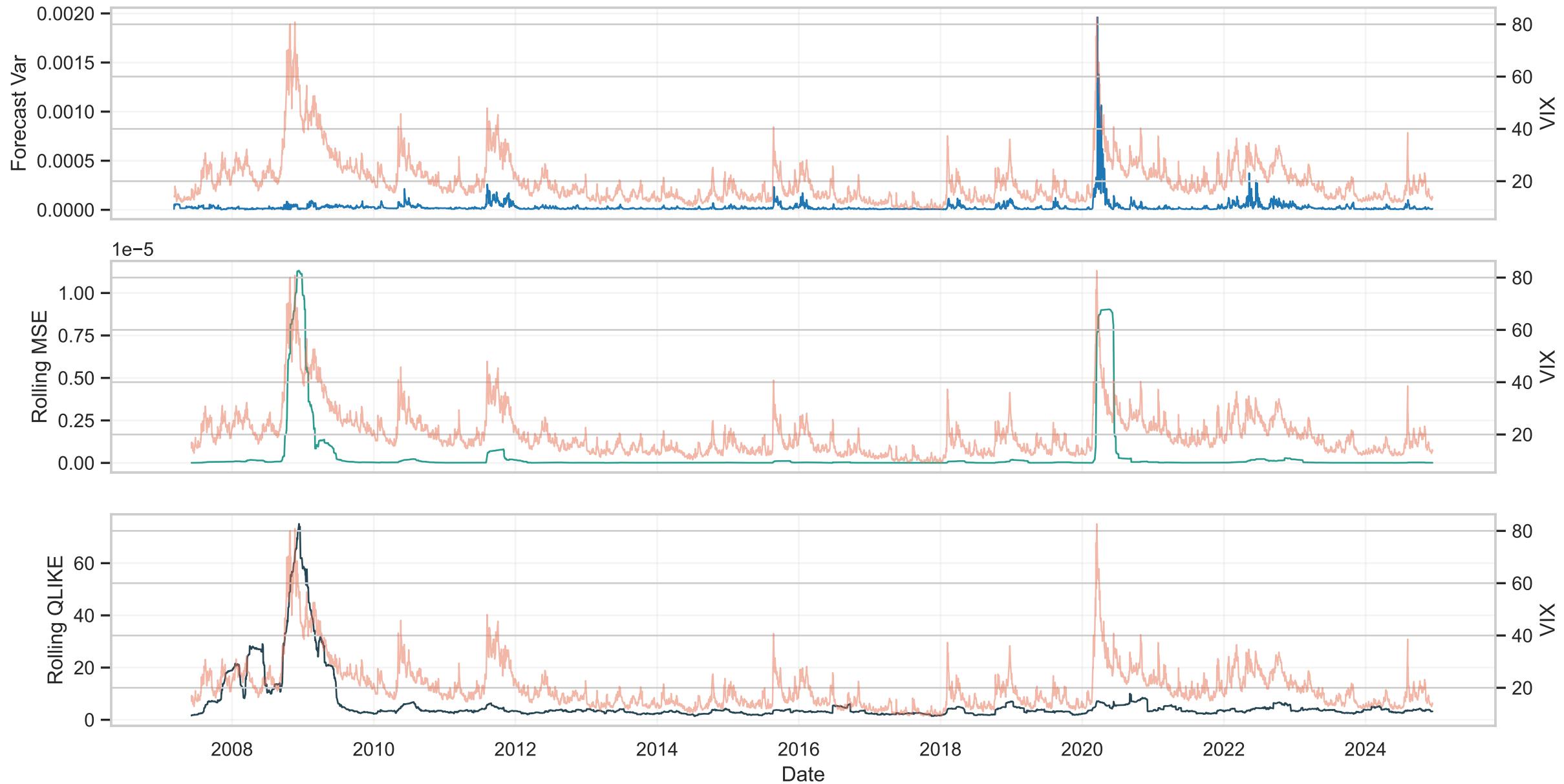
Pure LSTM: VIX and Forecast/Error Diagnostics



Hybrid GRU: VIX and Forecast/Error Diagnostics

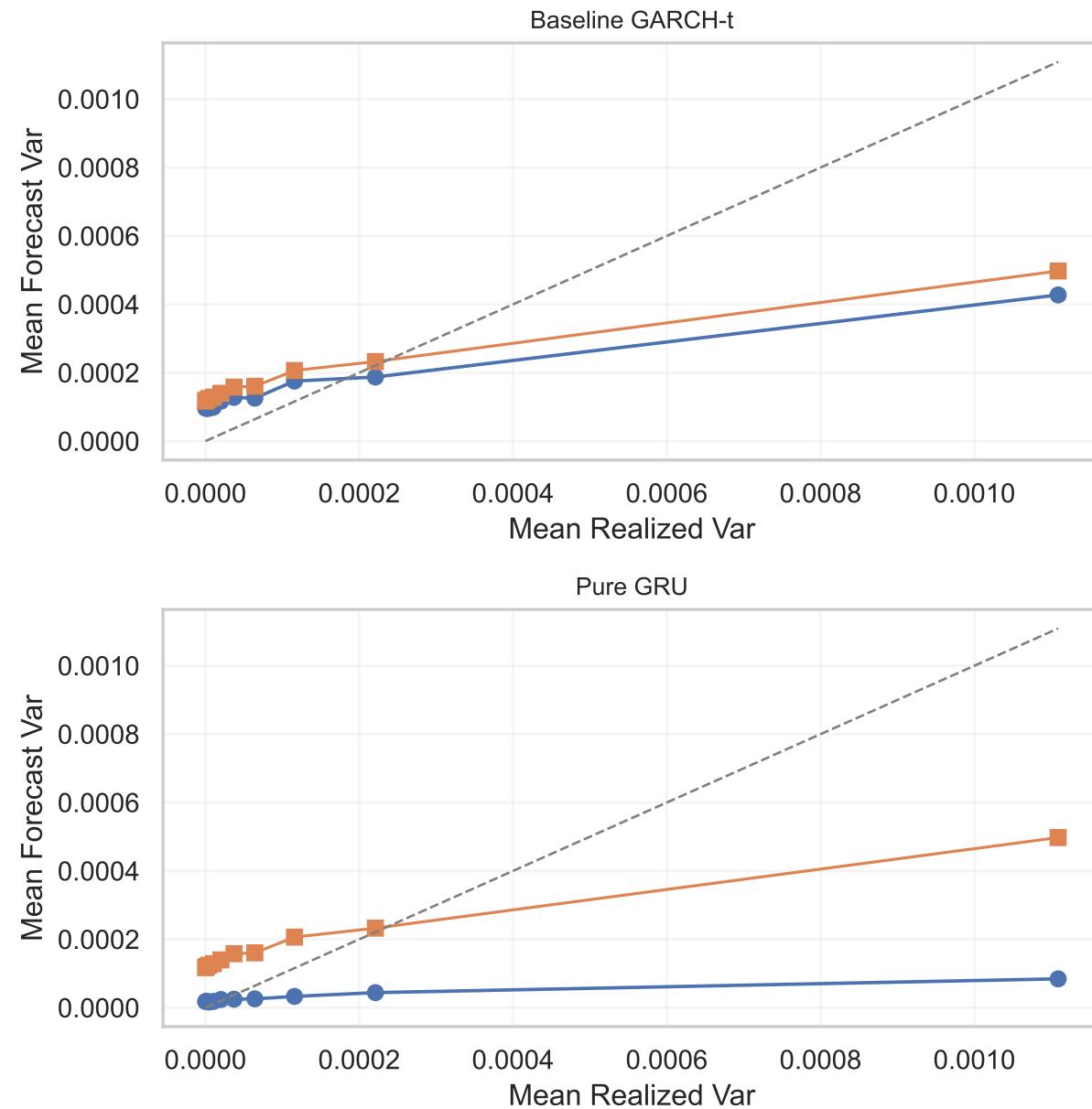
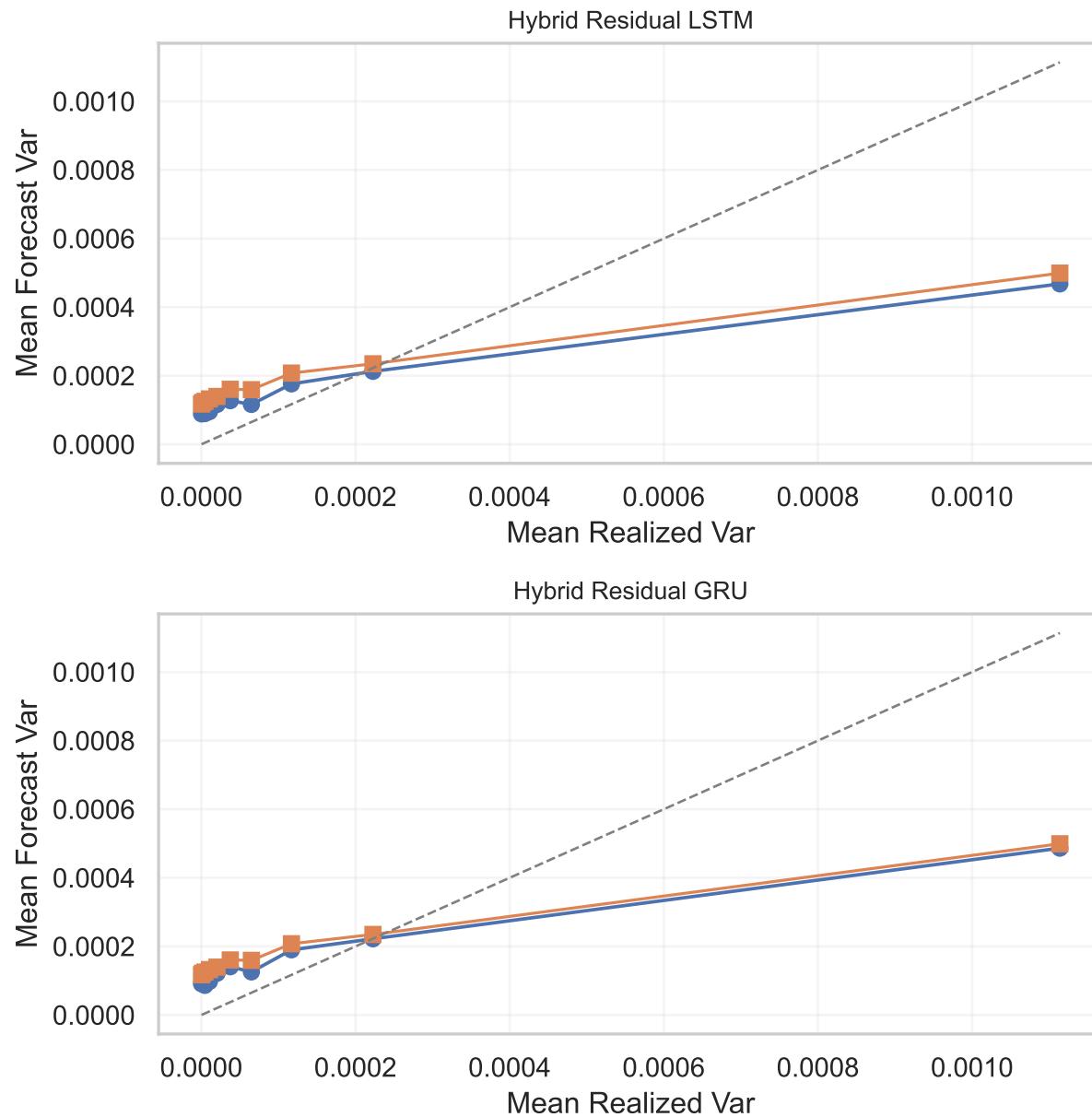


Hybrid LSTM: VIX and Forecast/Error Diagnostics



Calibration vs Realized Variance

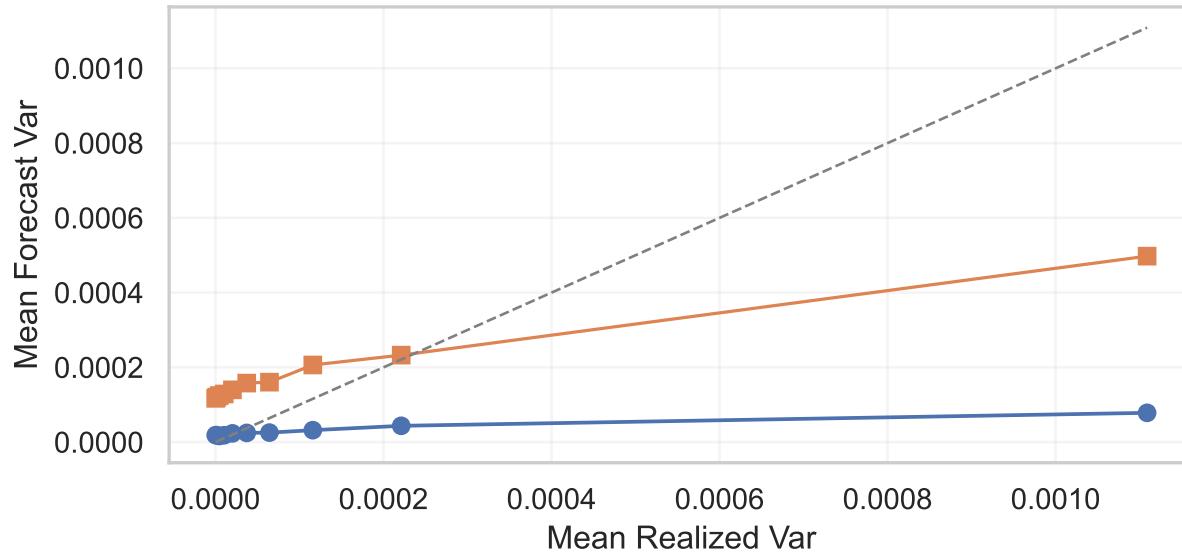
Model forecasts and VIX-implied variance by realized-variance decile



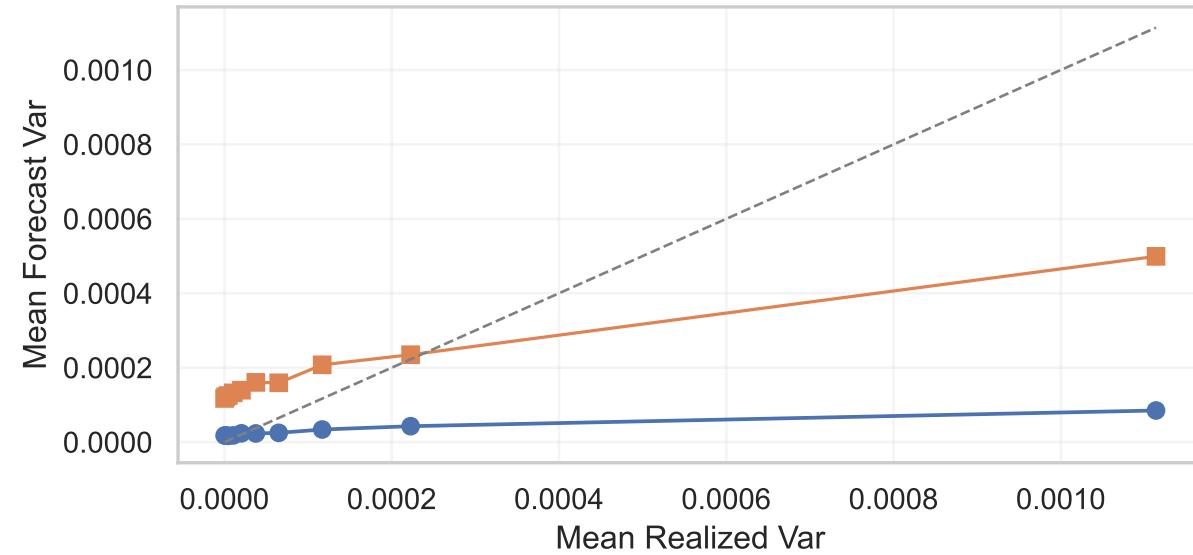
Calibration vs Realized Variance

Model forecasts and VIX-implied variance by realized-variance decile

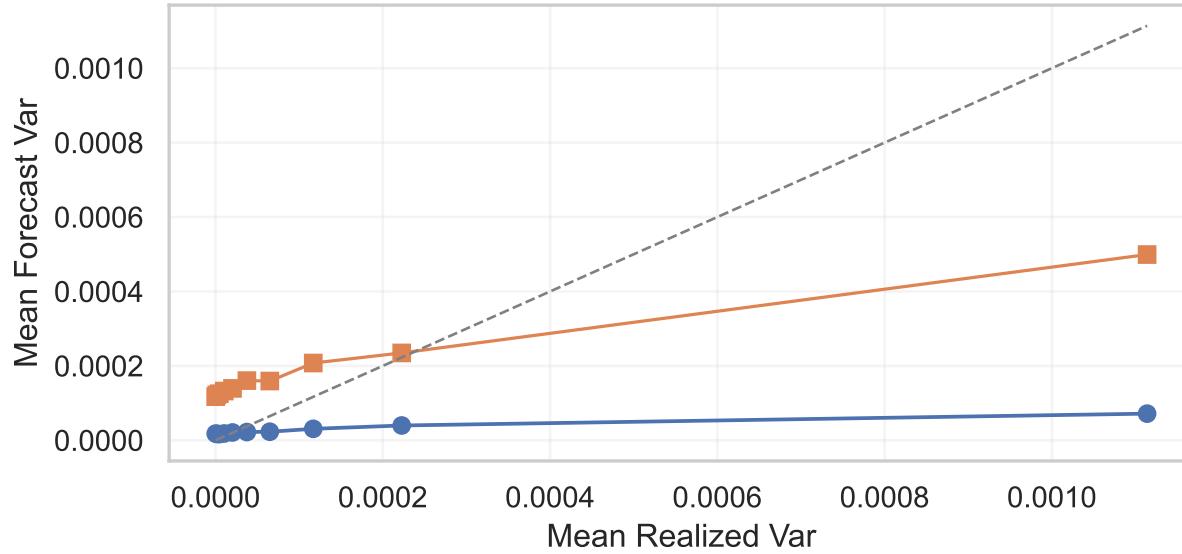
Pure LSTM



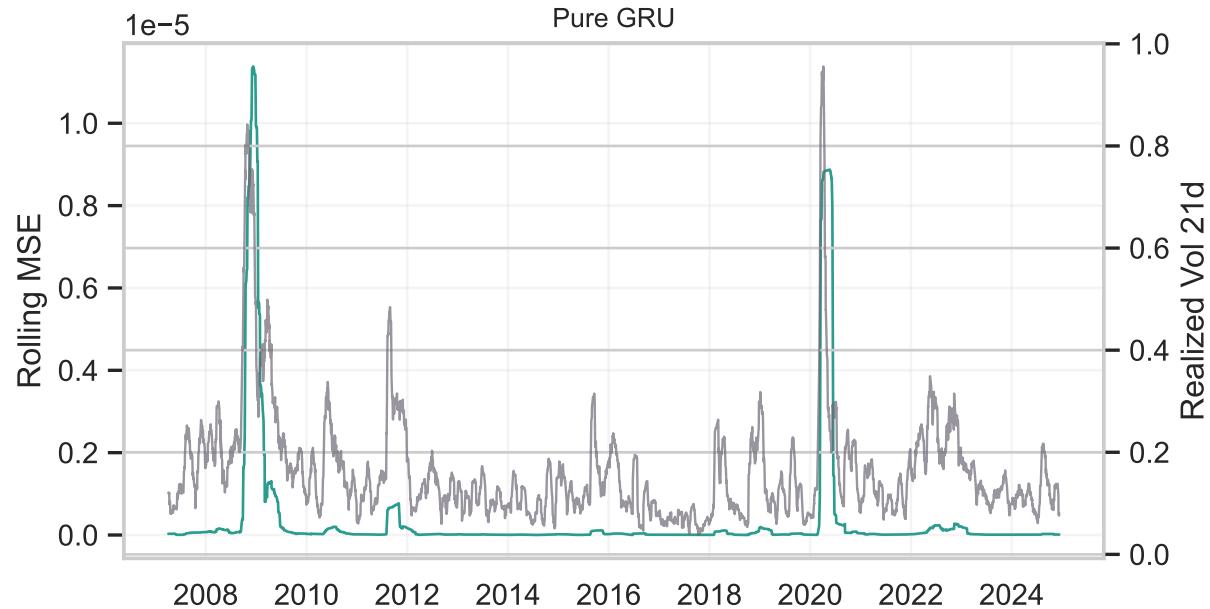
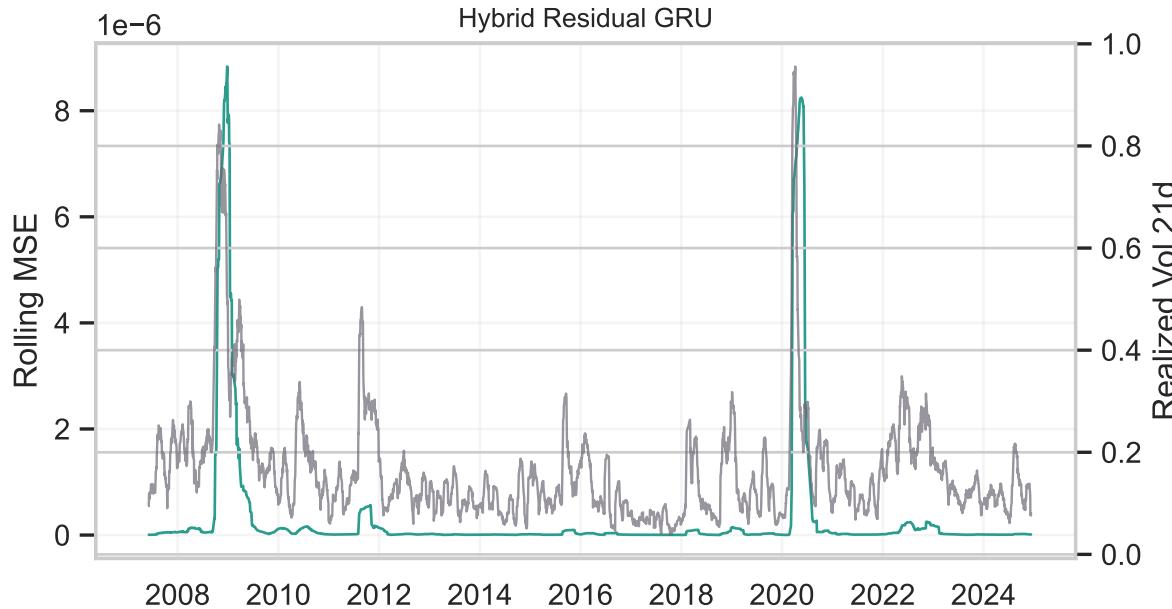
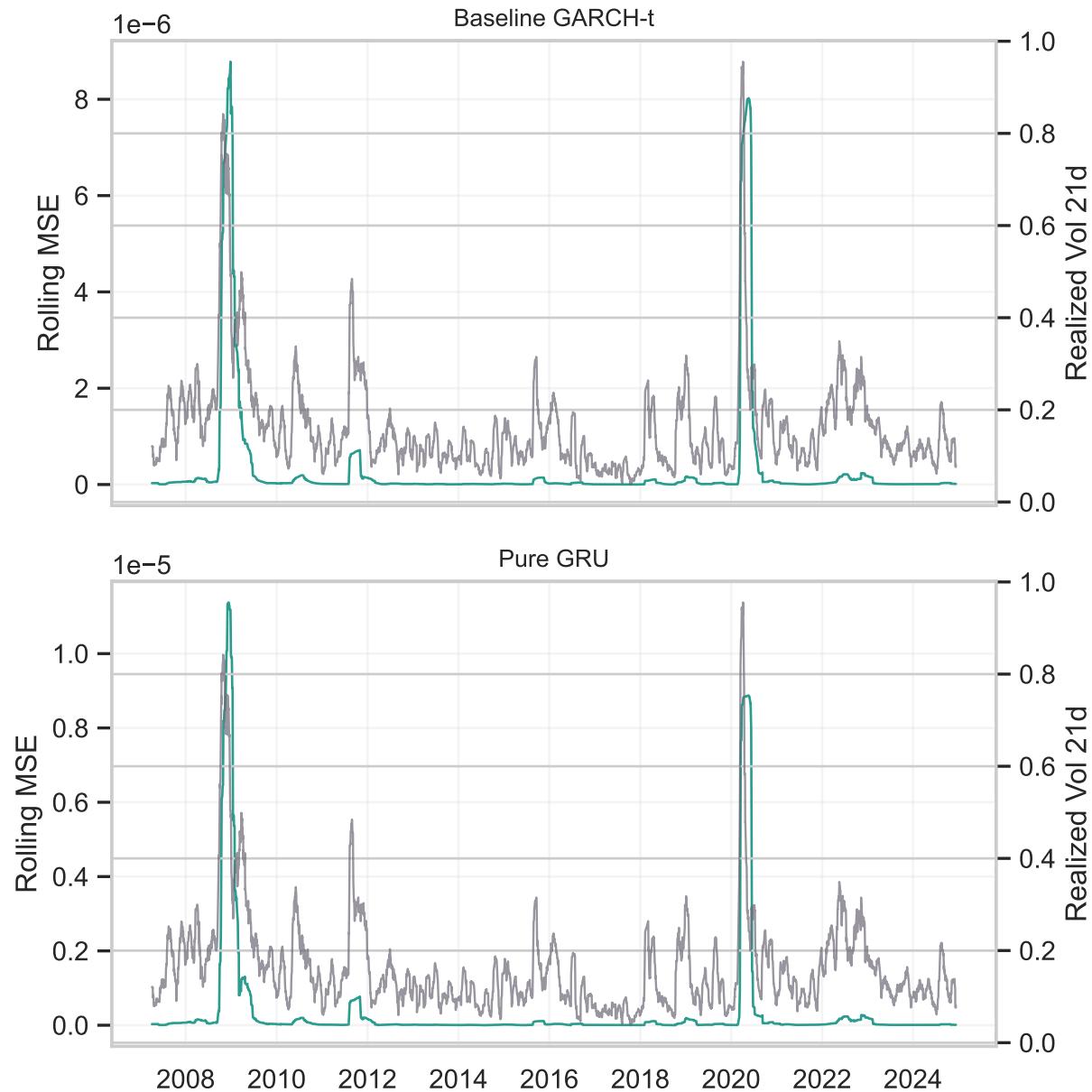
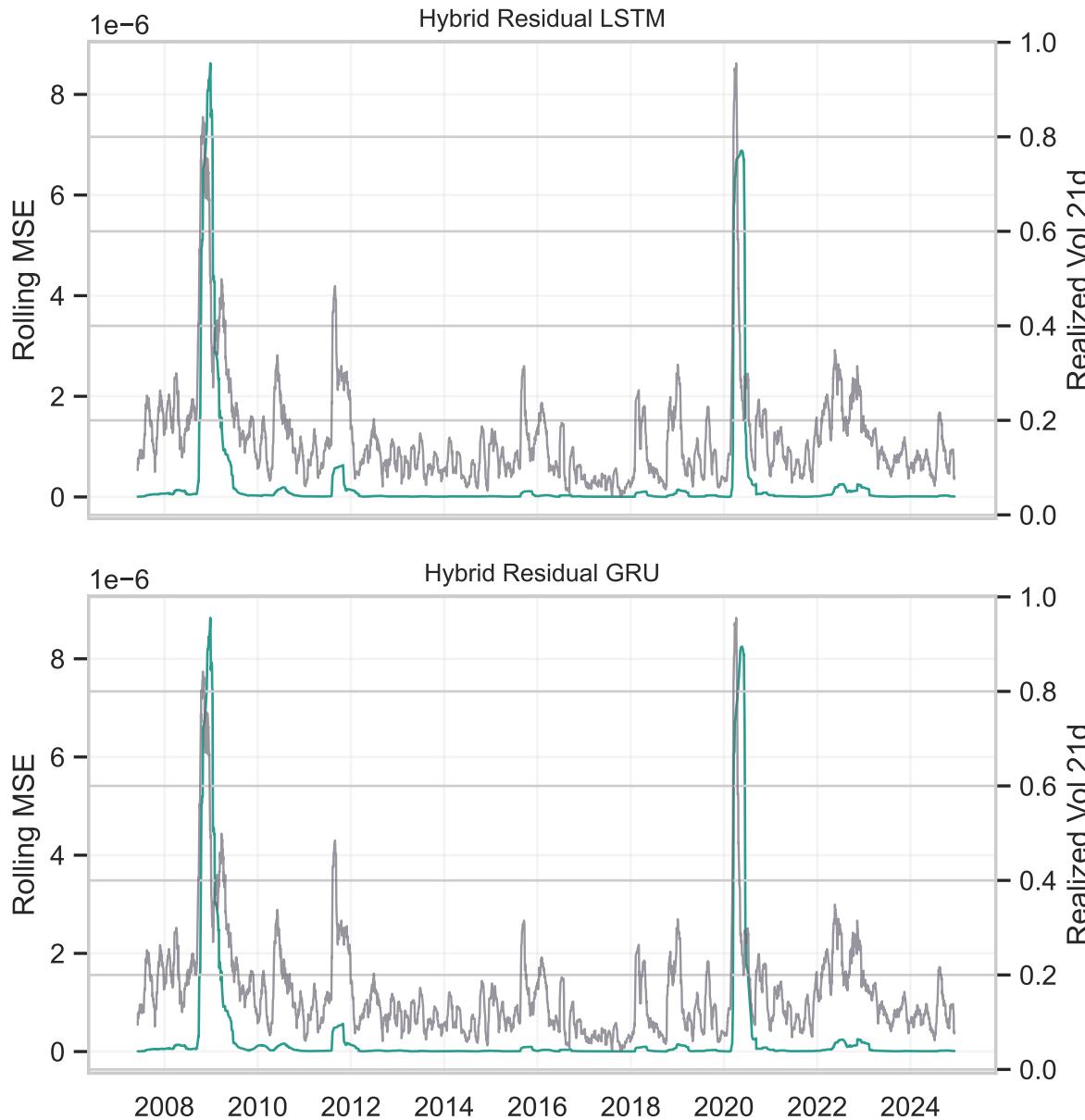
Hybrid GRU



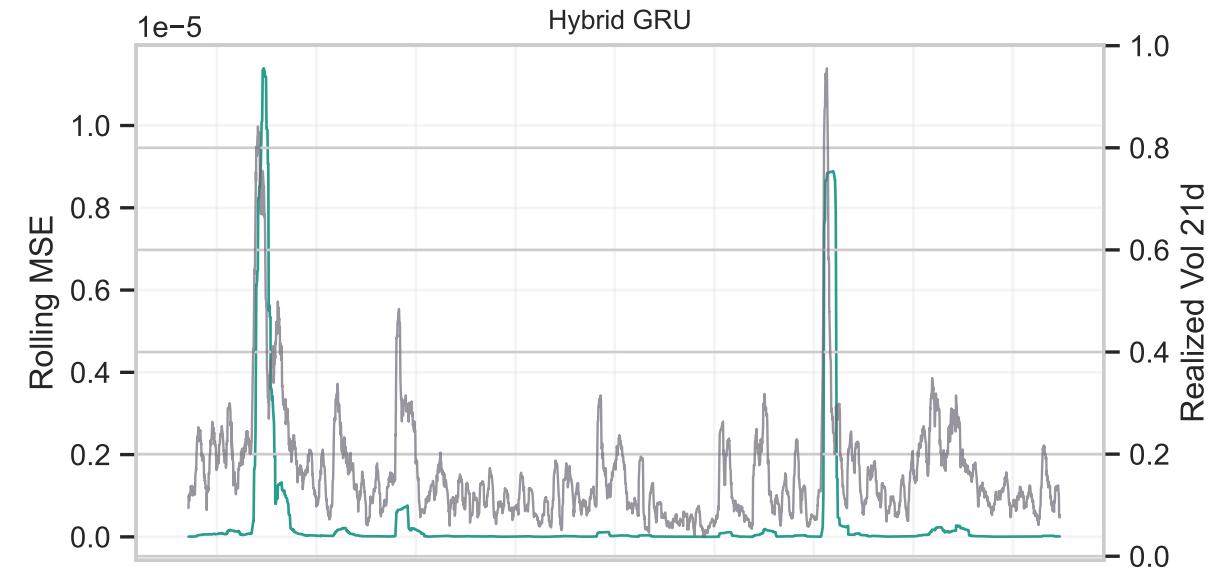
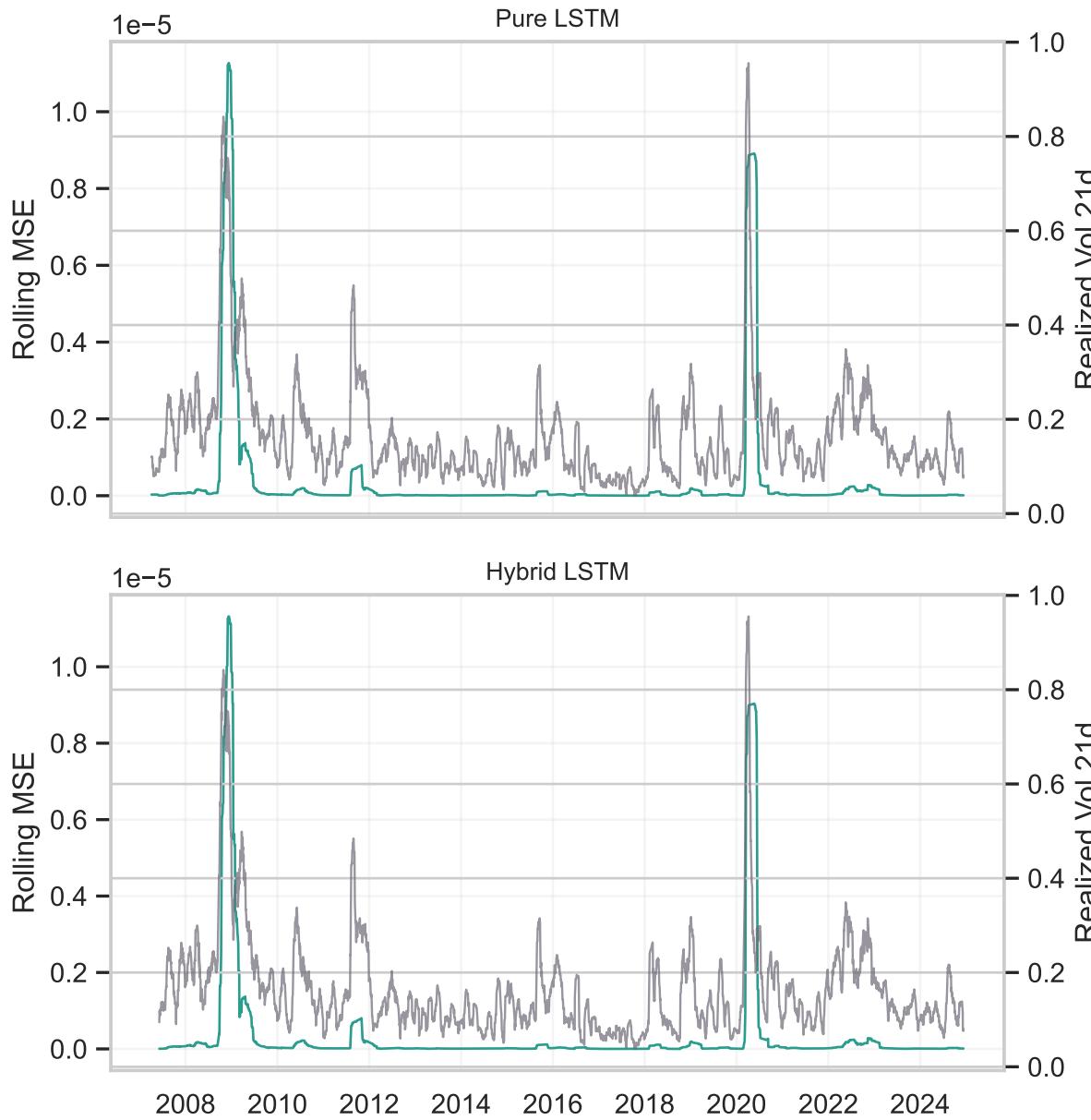
Hybrid LSTM



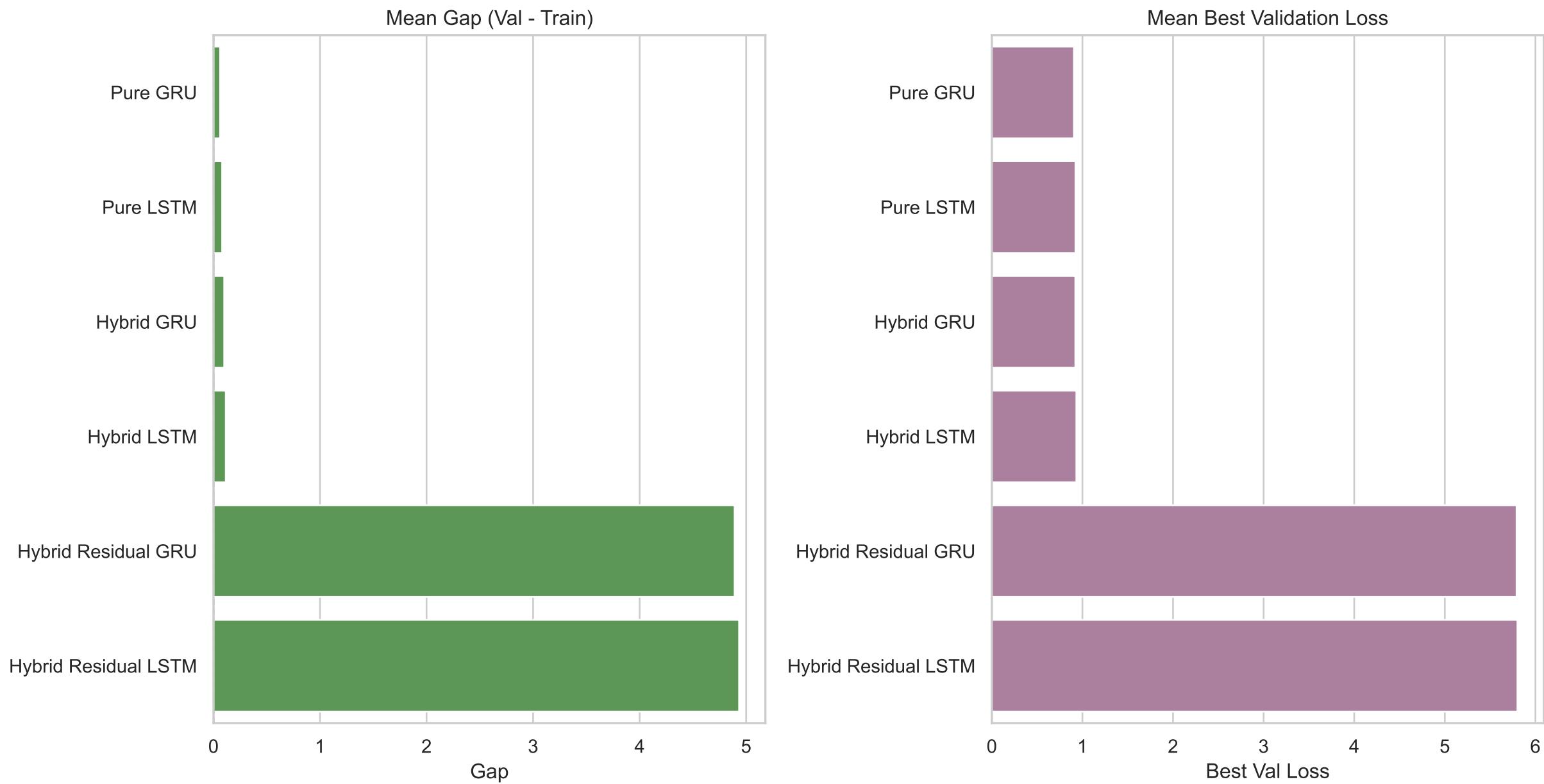
Rolling 63D MSE vs Realized Volatility



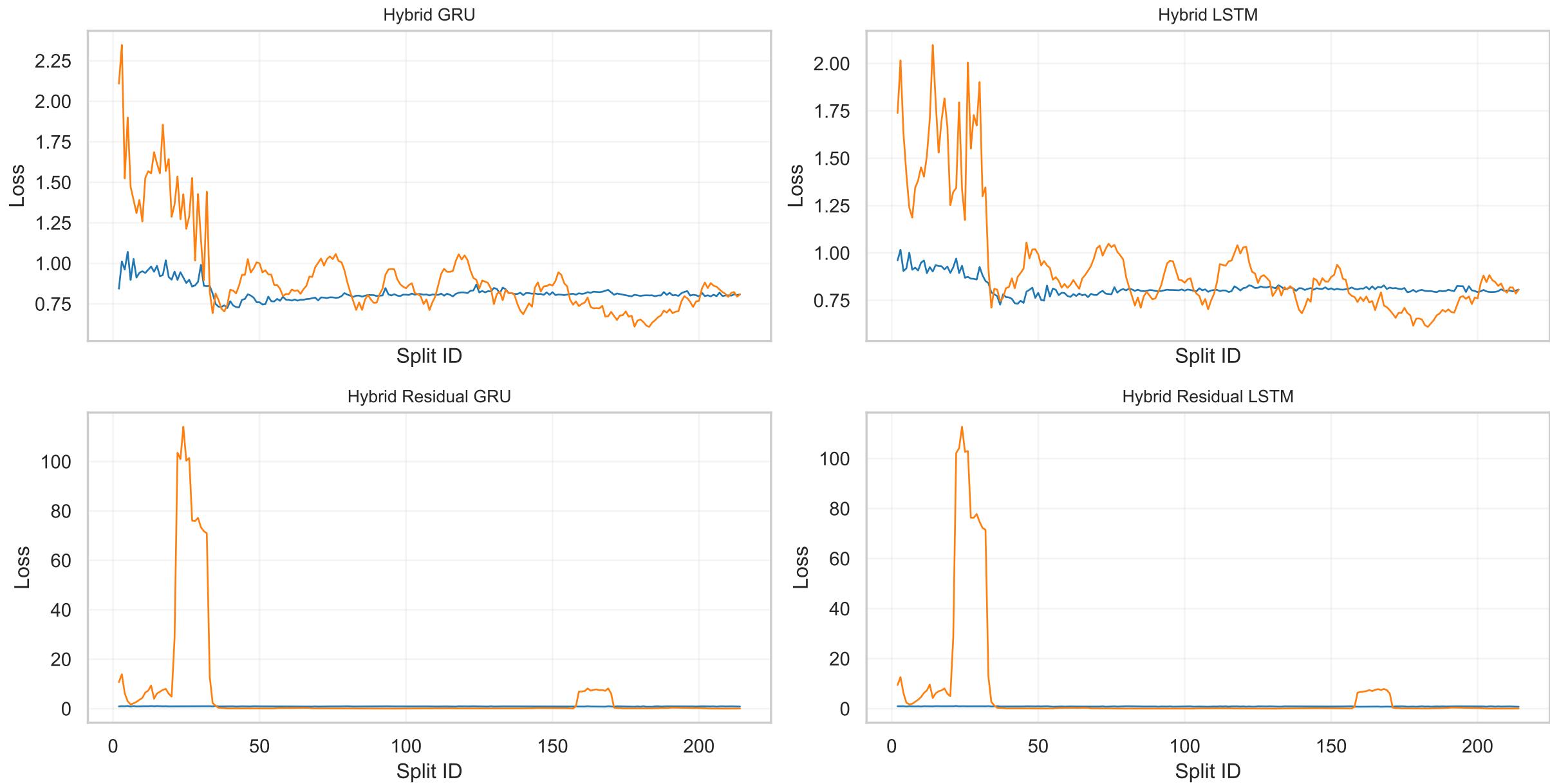
Rolling 63D MSE vs Realized Volatility



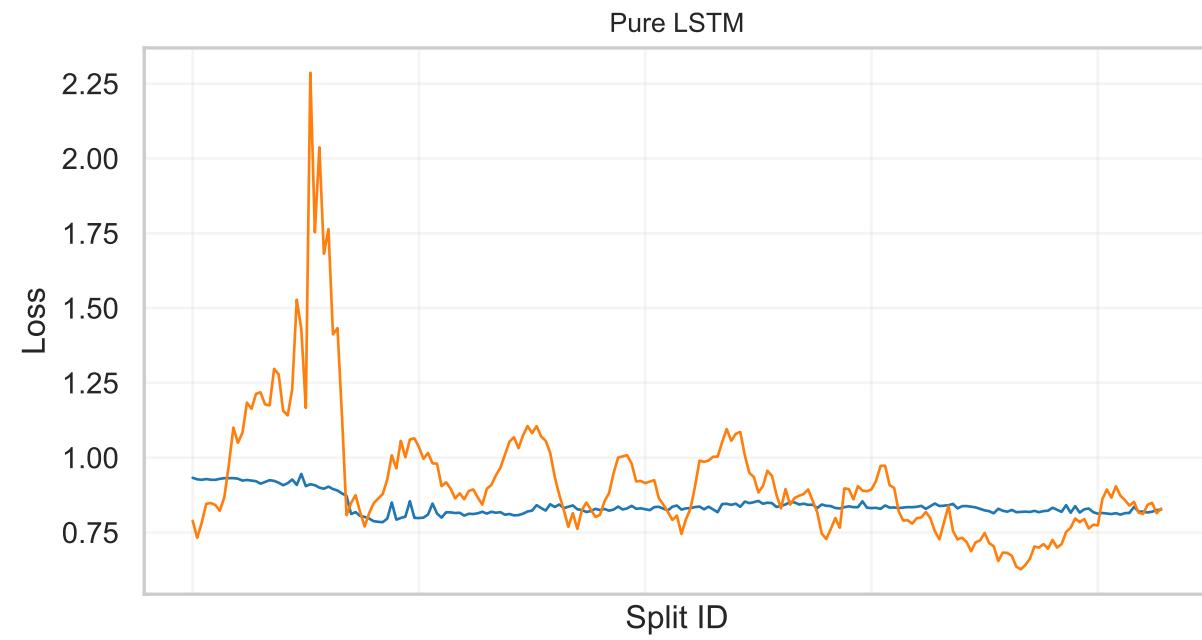
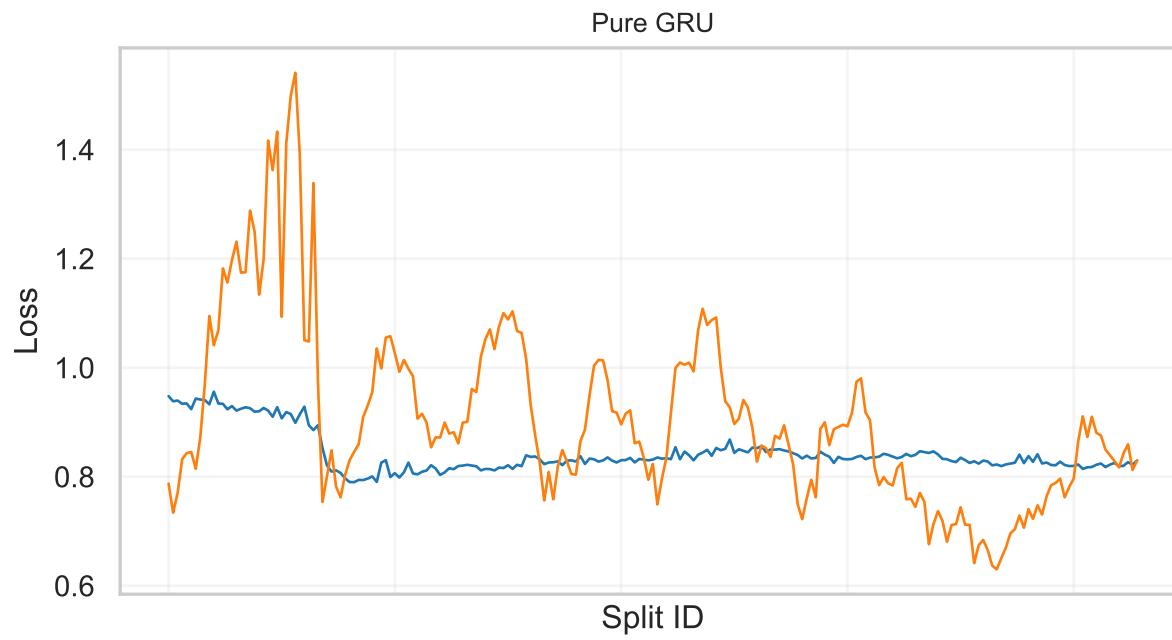
Overfit Diagnostics (Best Epoch Across Rolling Splits)



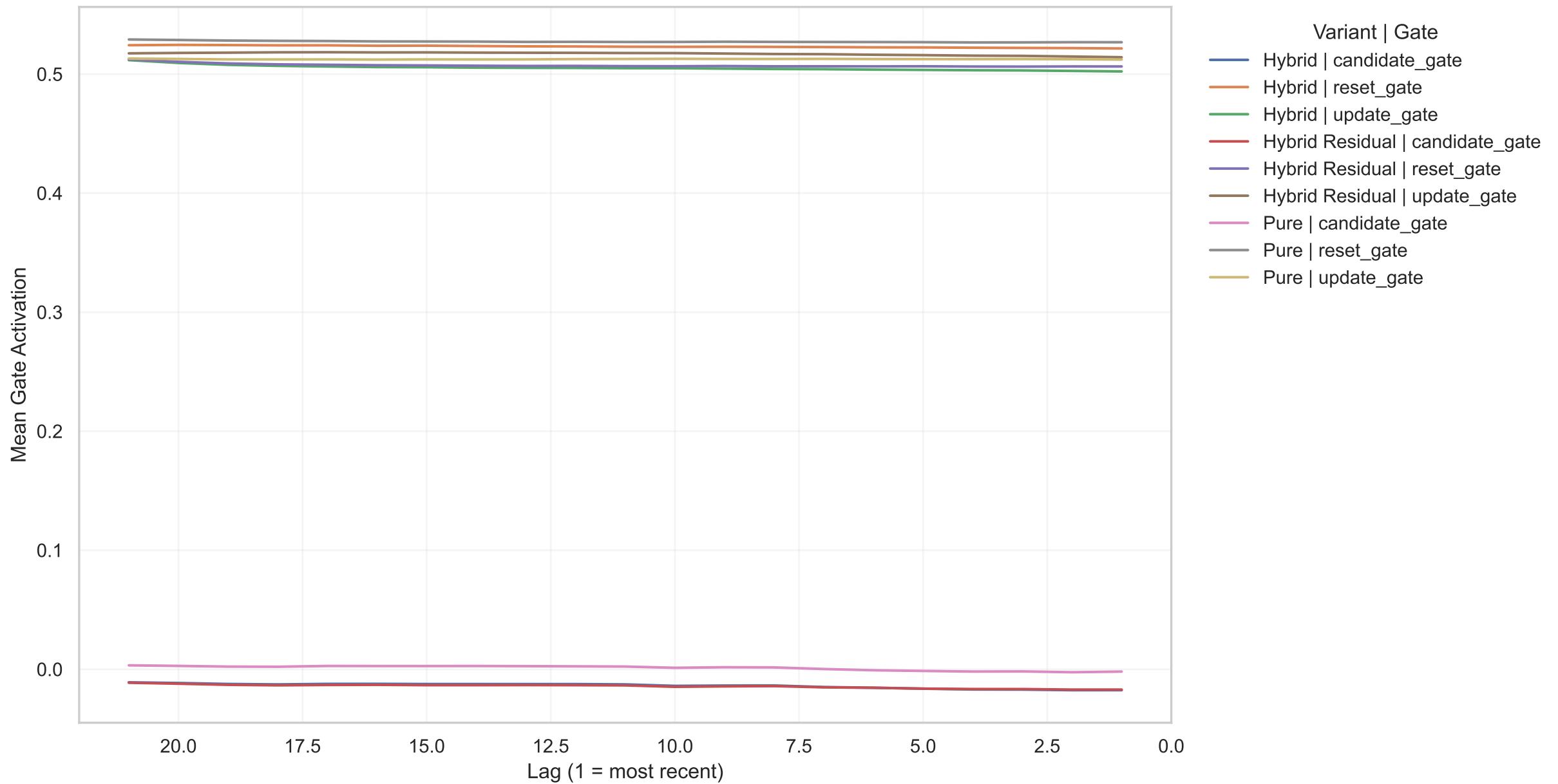
Best Loss by Rolling Split



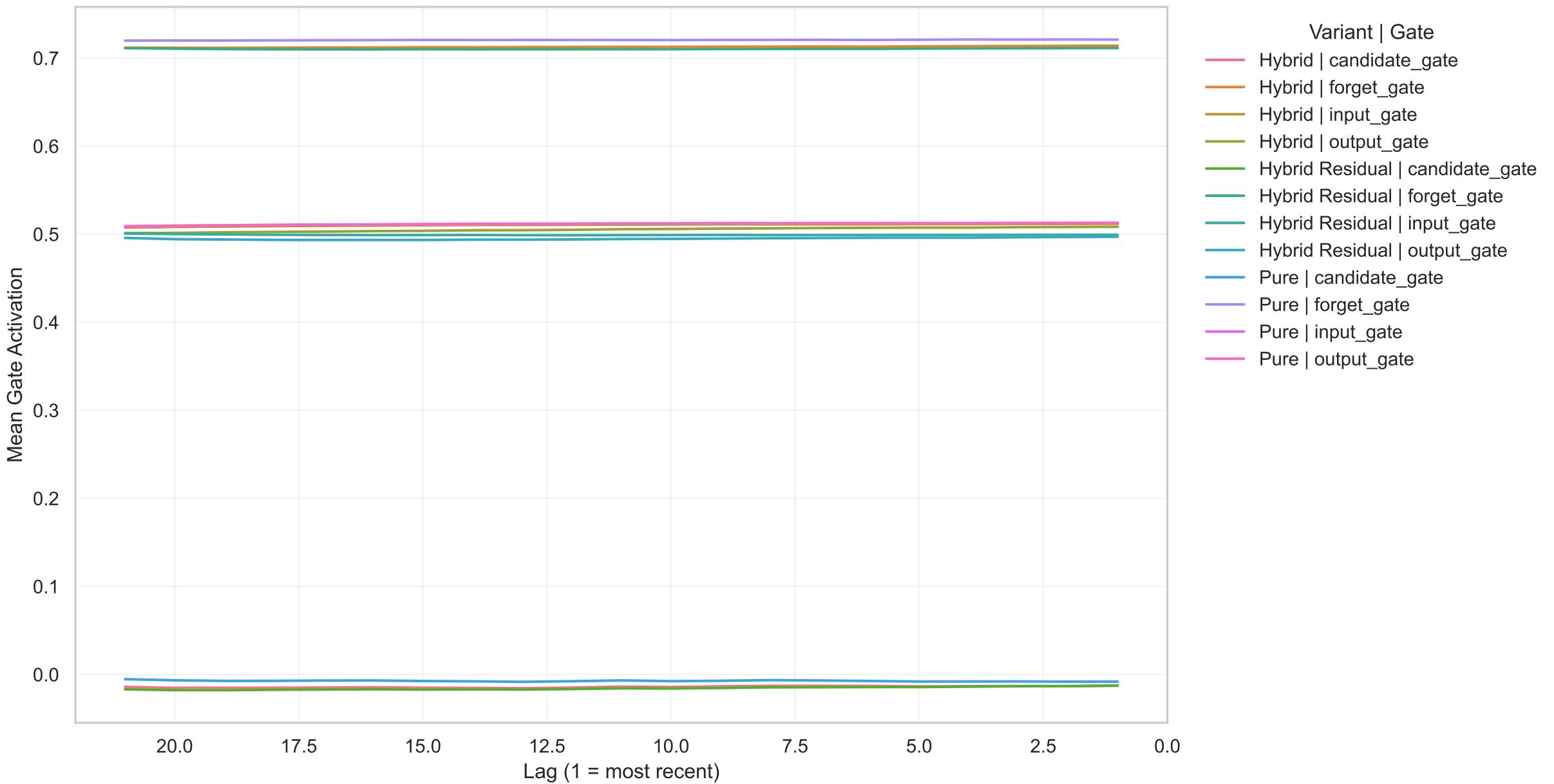
Best Loss by Rolling Split



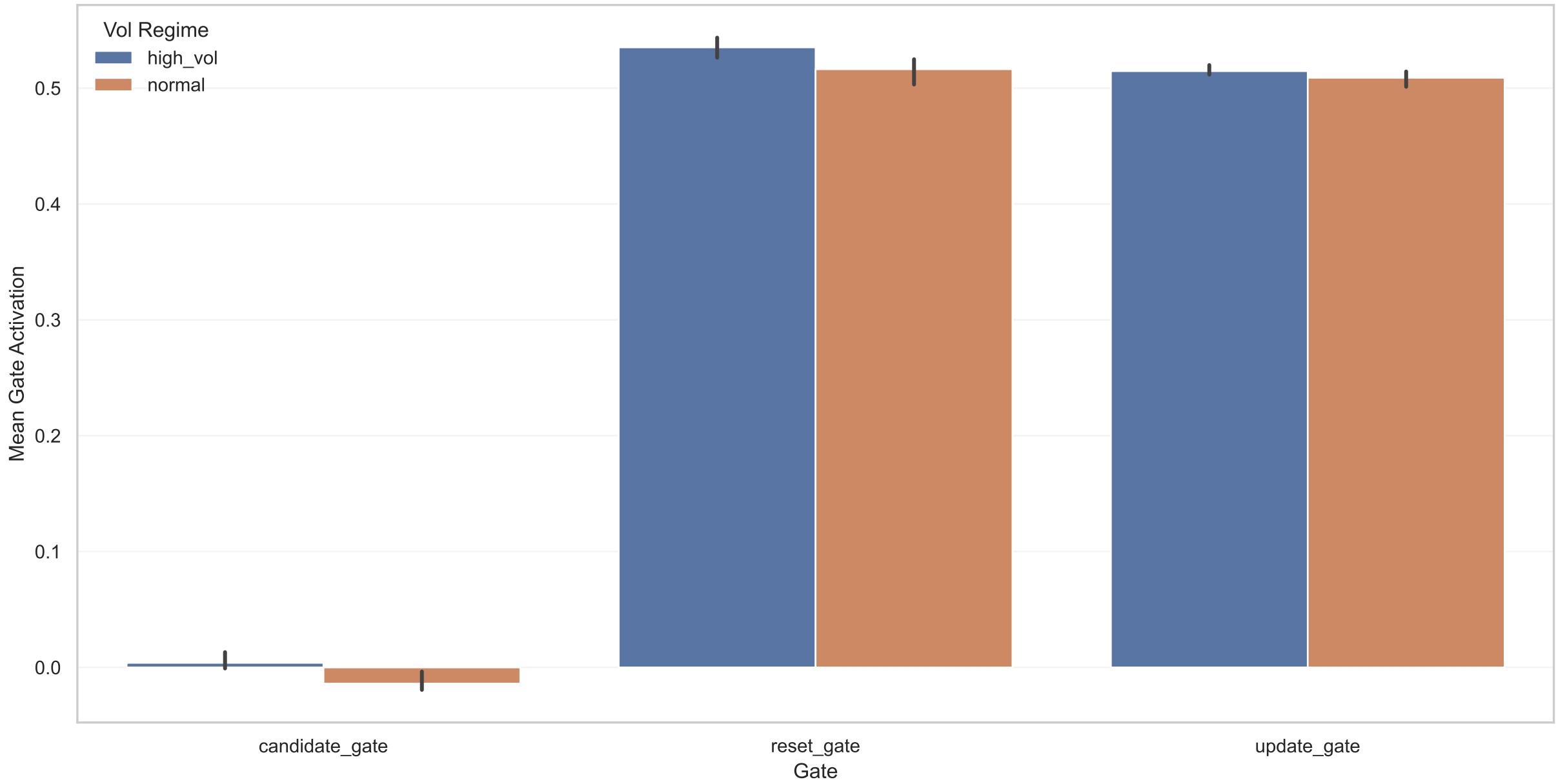
GRU Gate Profiles by Lag



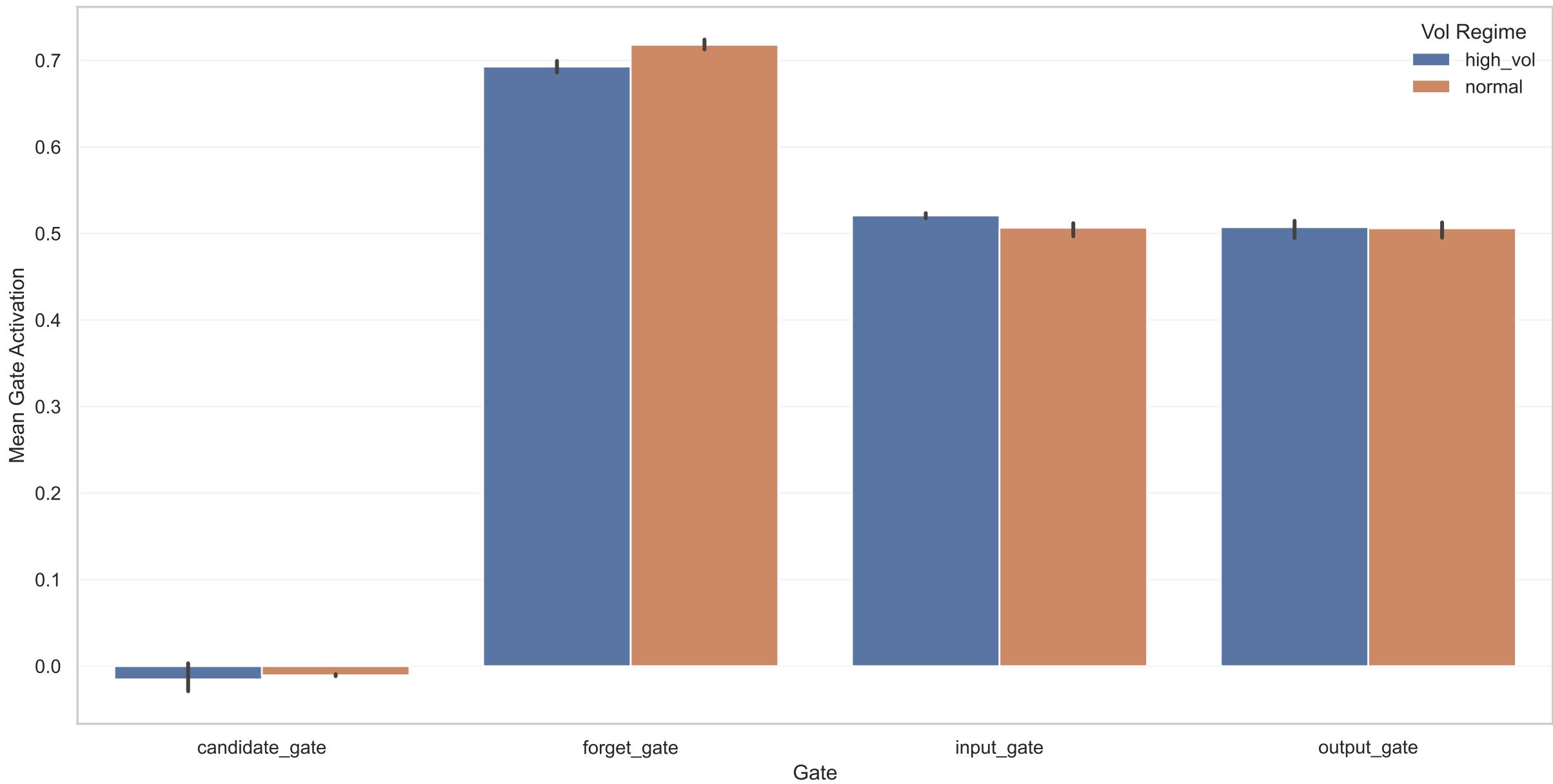
LSTM Gate Profiles by Lag



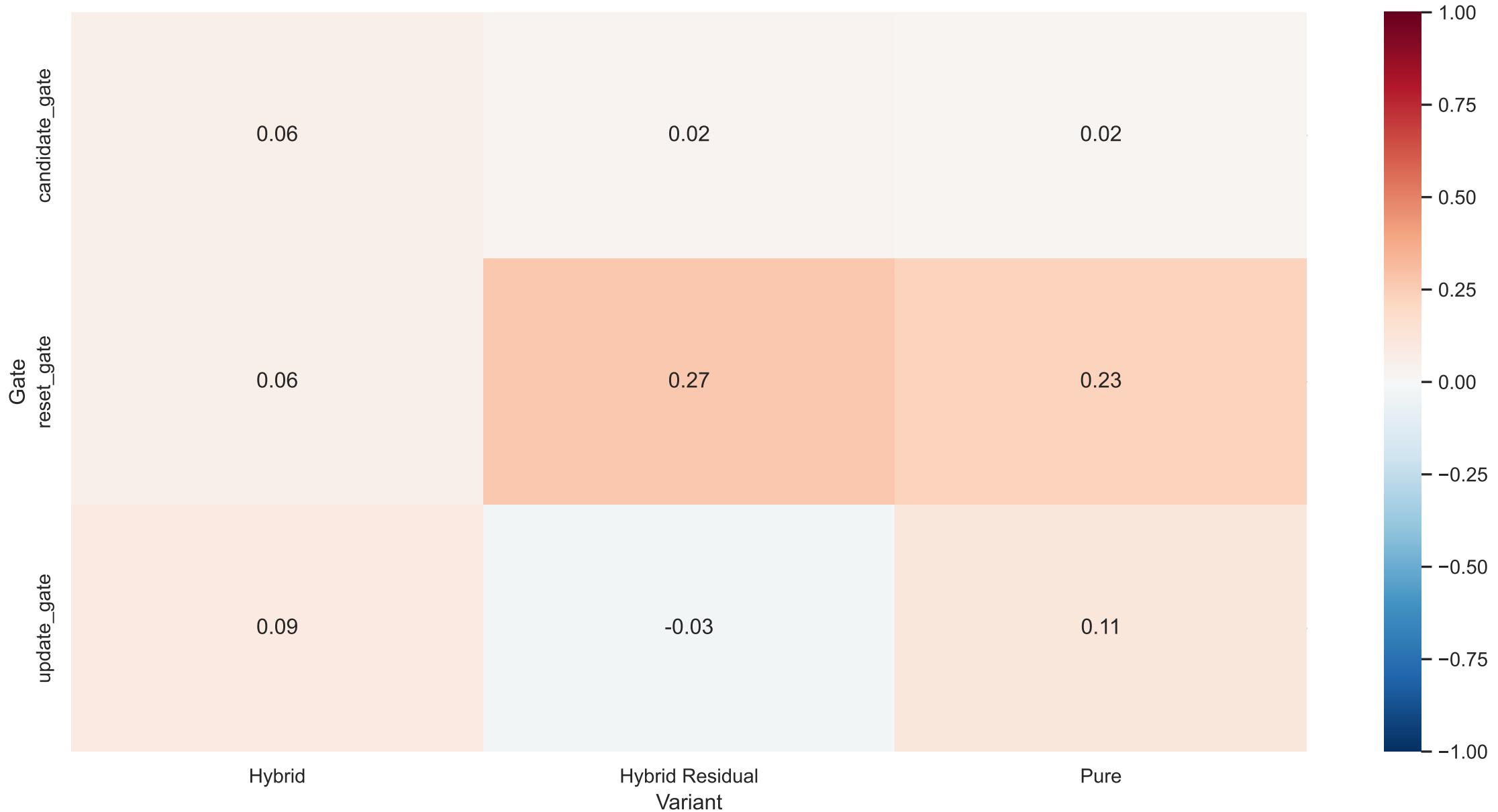
GRU Lag-1 Gate Activation by Regime



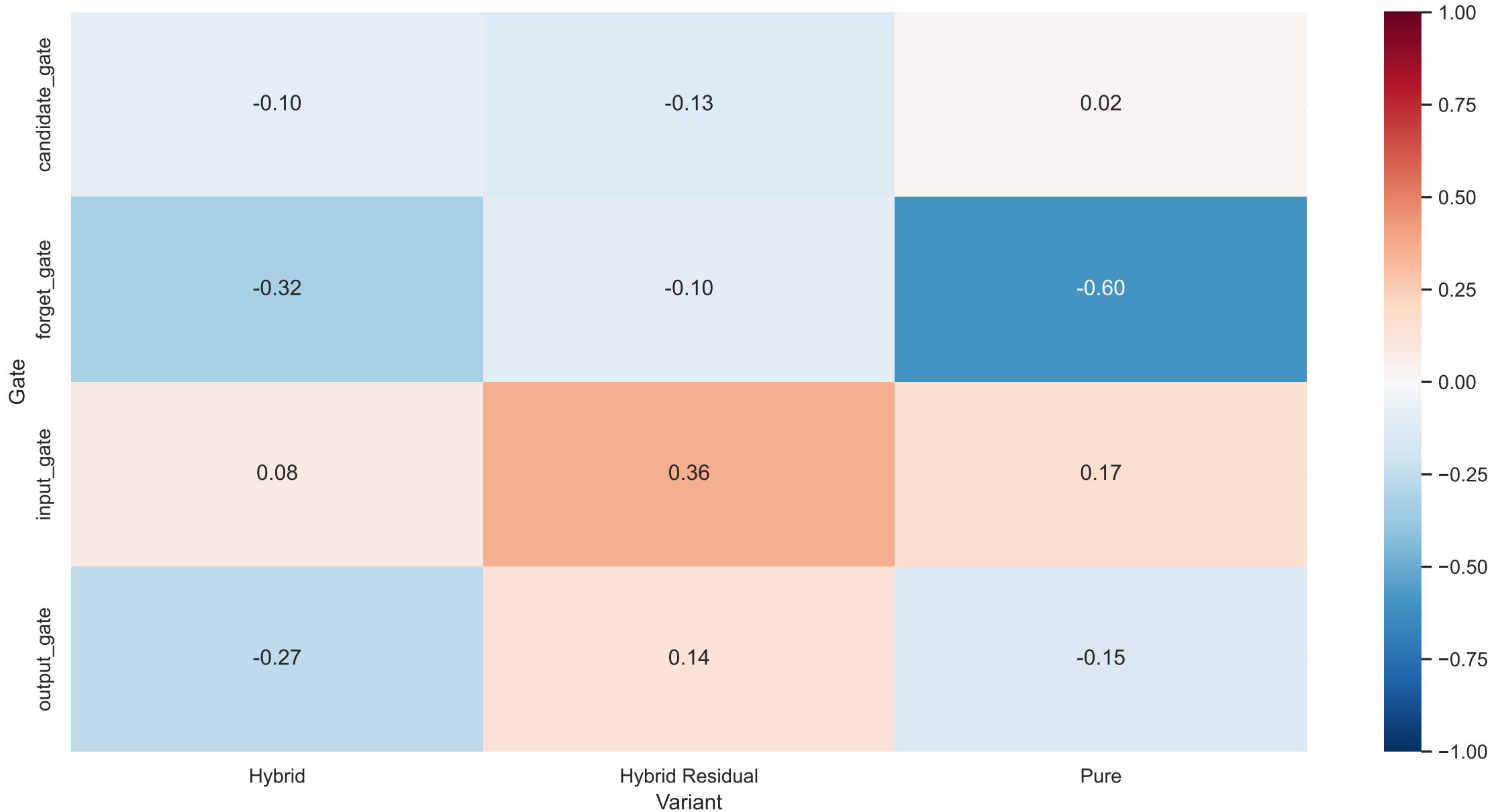
LSTM Lag-1 Gate Activation by Regime



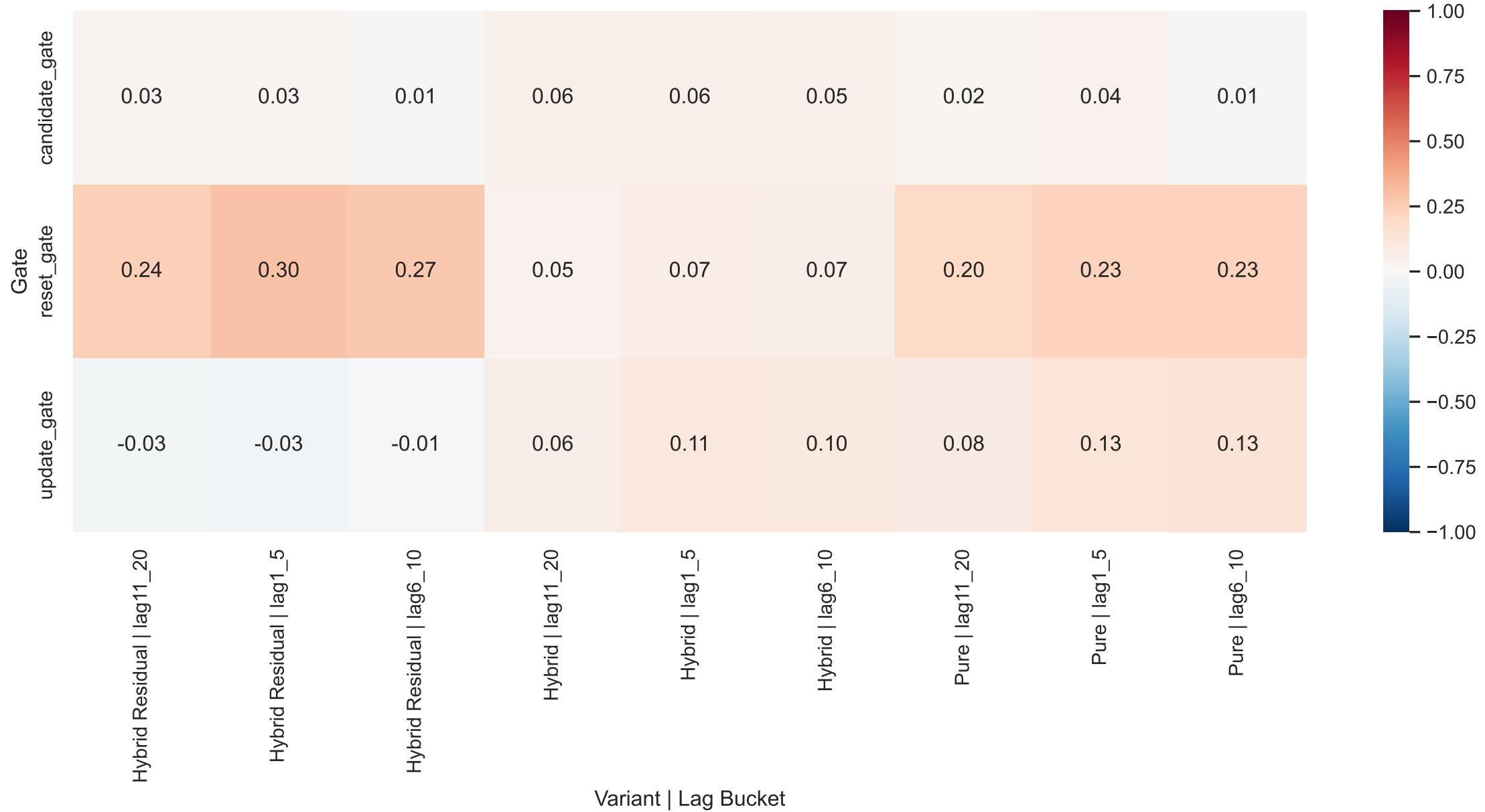
GRU Gate-VIX Correlation (Pearson)



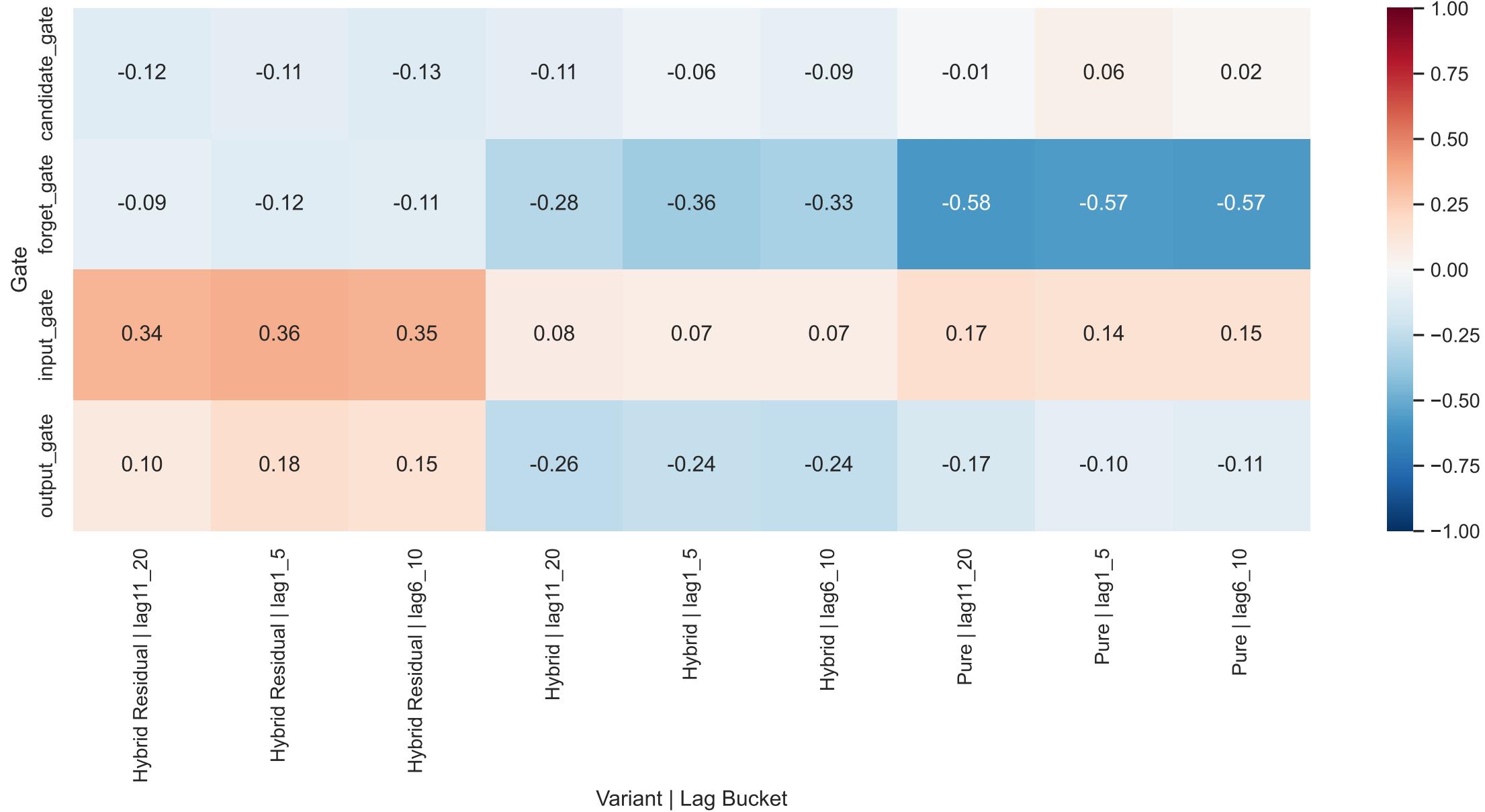
LSTM Gate-VIX Correlation (Pearson)



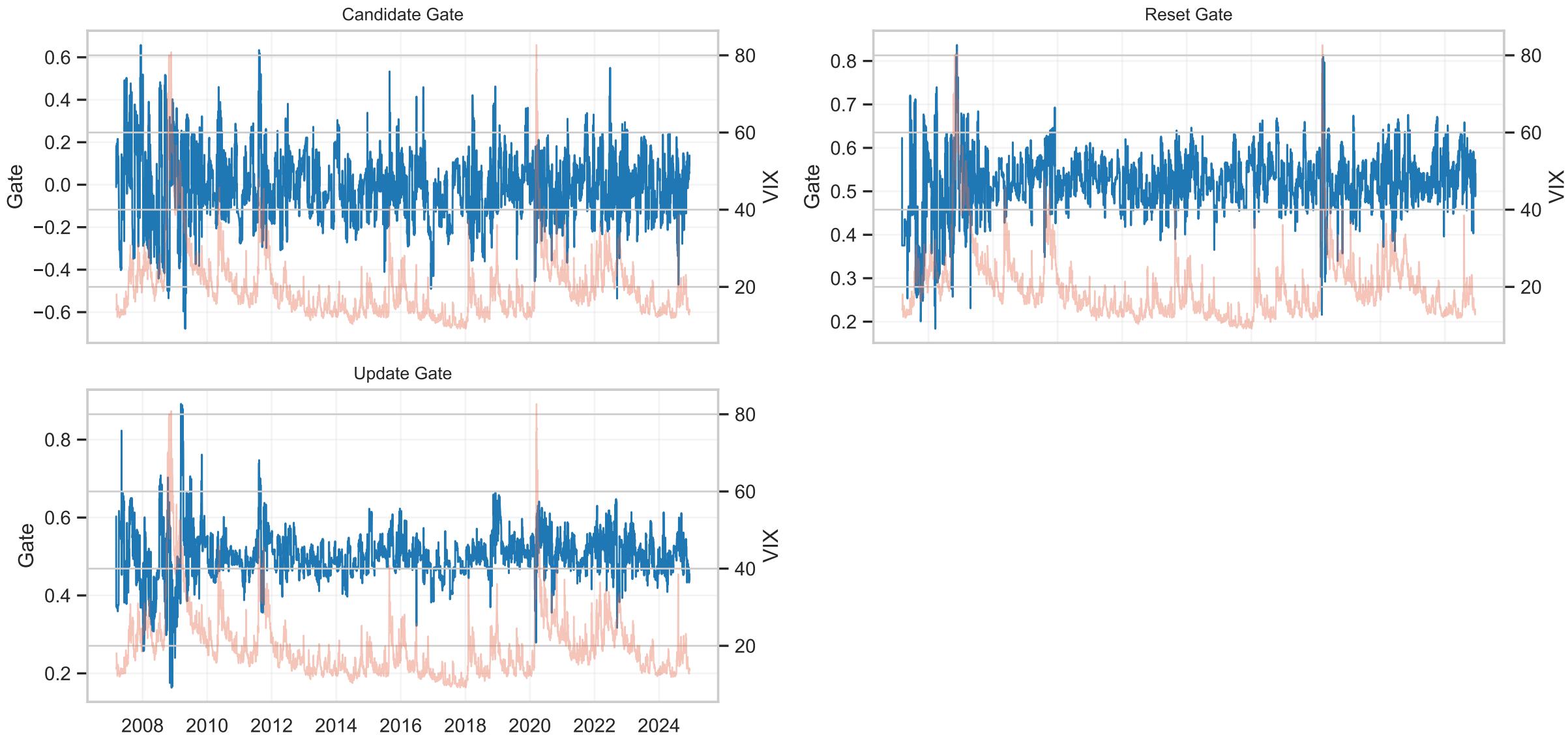
GRU Bucket Gate-VIX Correlation (Pearson)



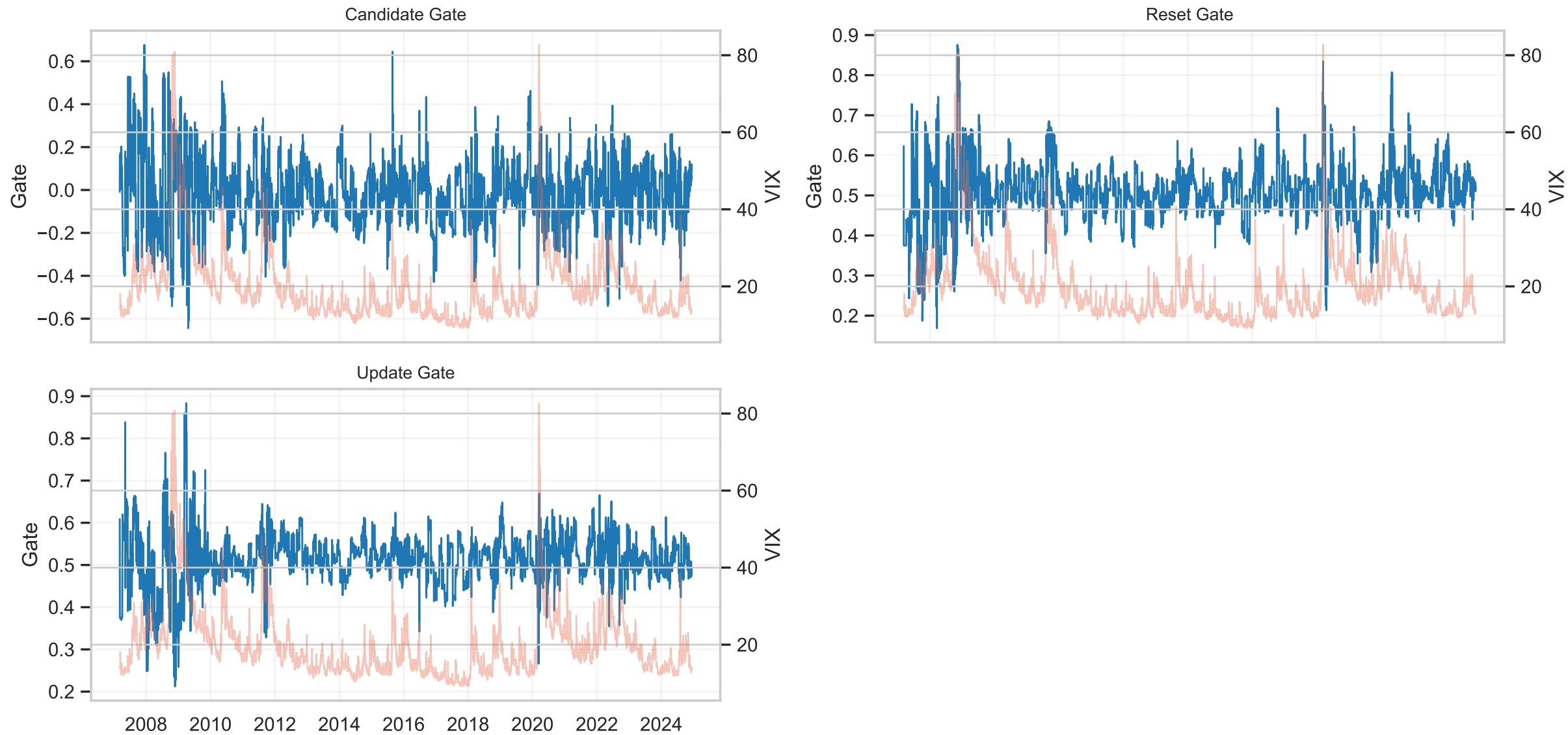
LSTM Bucket Gate-VIX Correlation (Pearson)



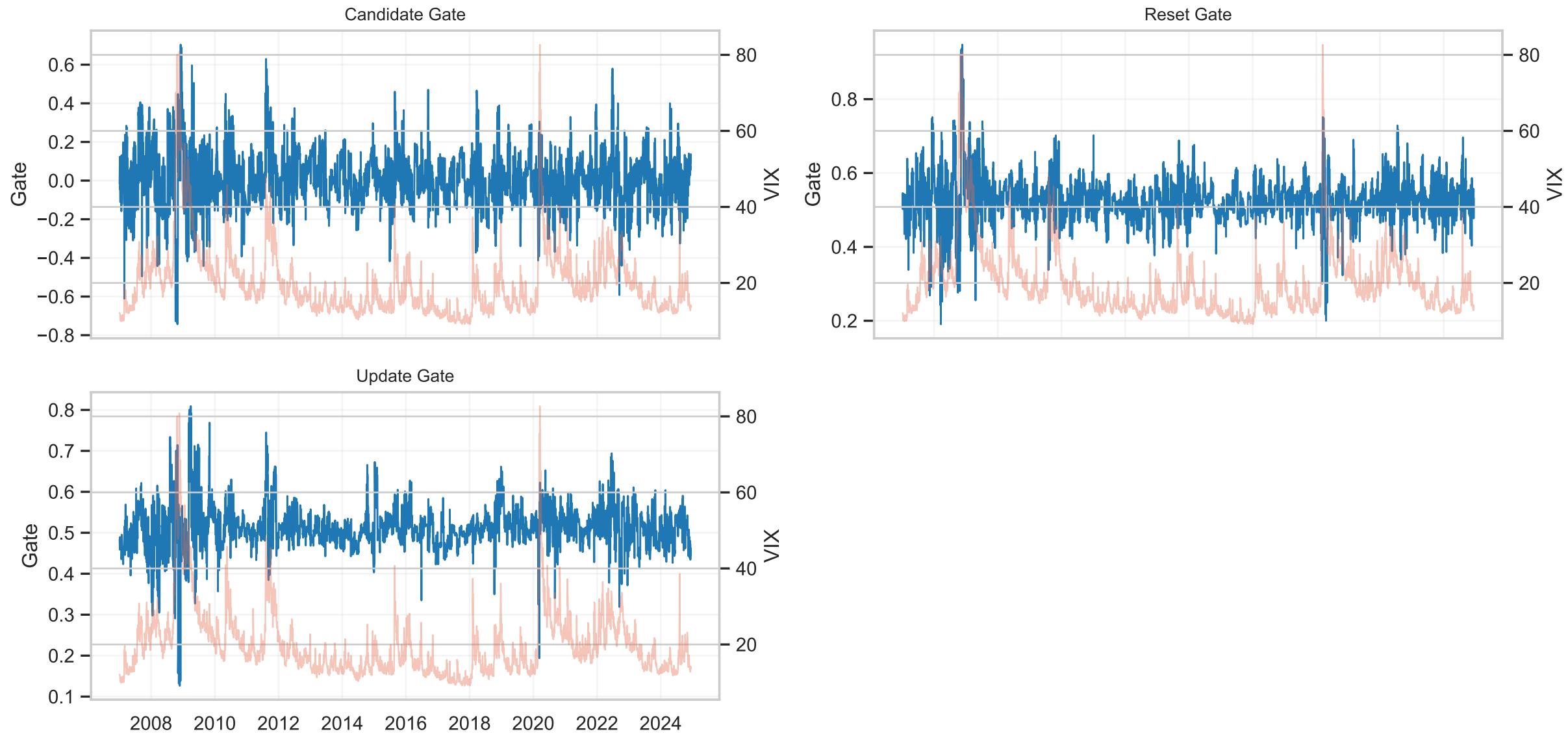
GRU | Hybrid: Lag-1 Gate vs VIX



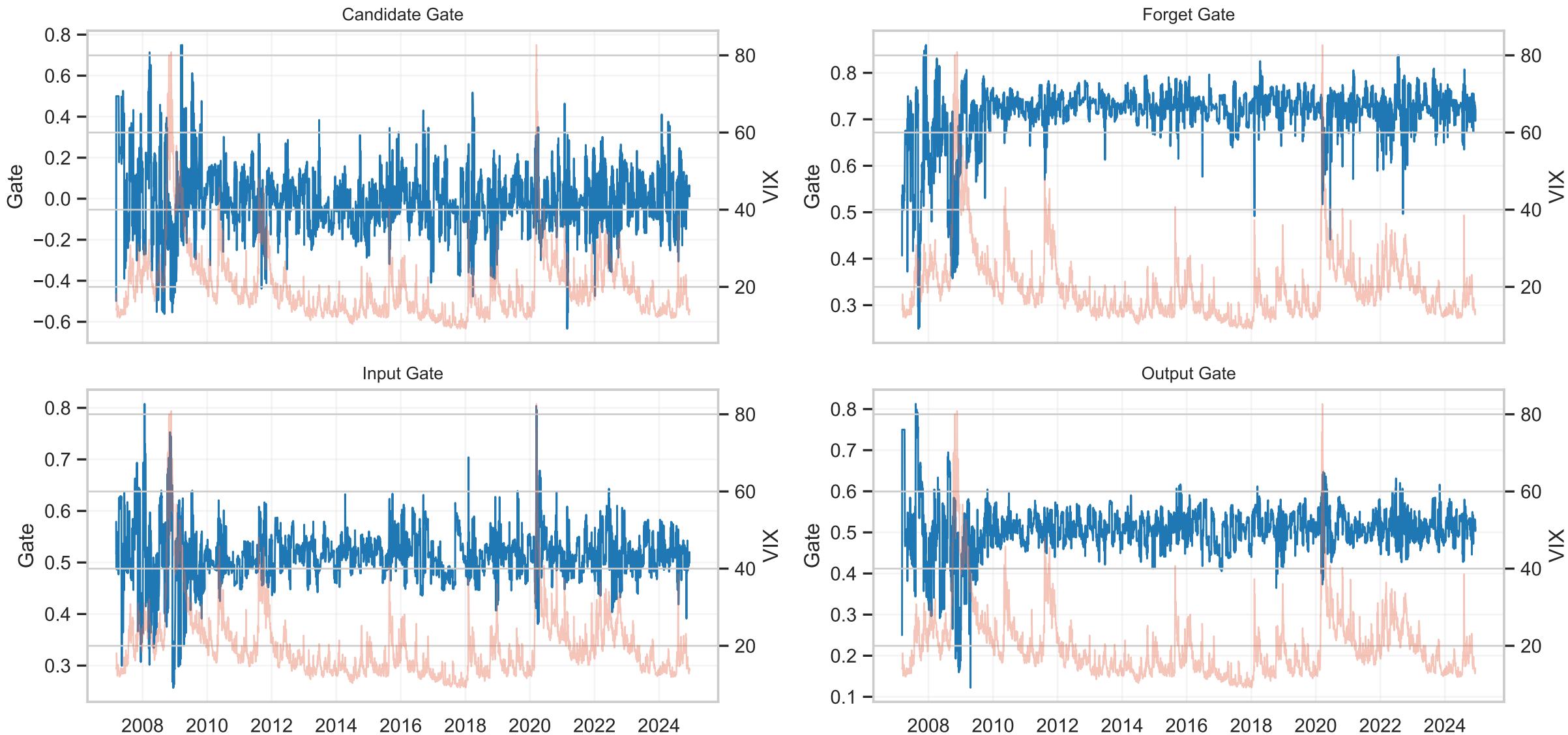
GRU | Hybrid Residual: Lag-1 Gate vs VIX



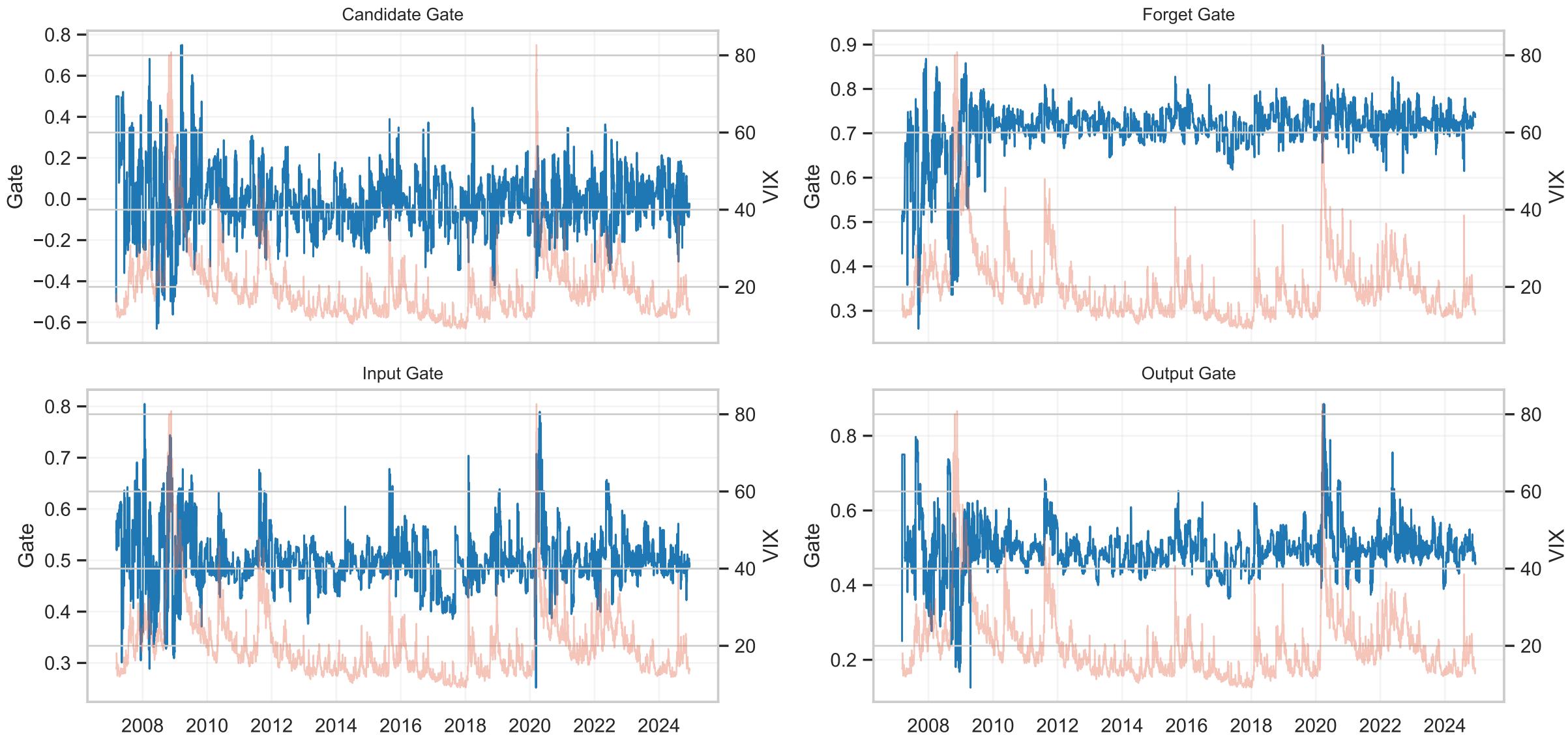
GRU | Pure: Lag-1 Gate vs VIX



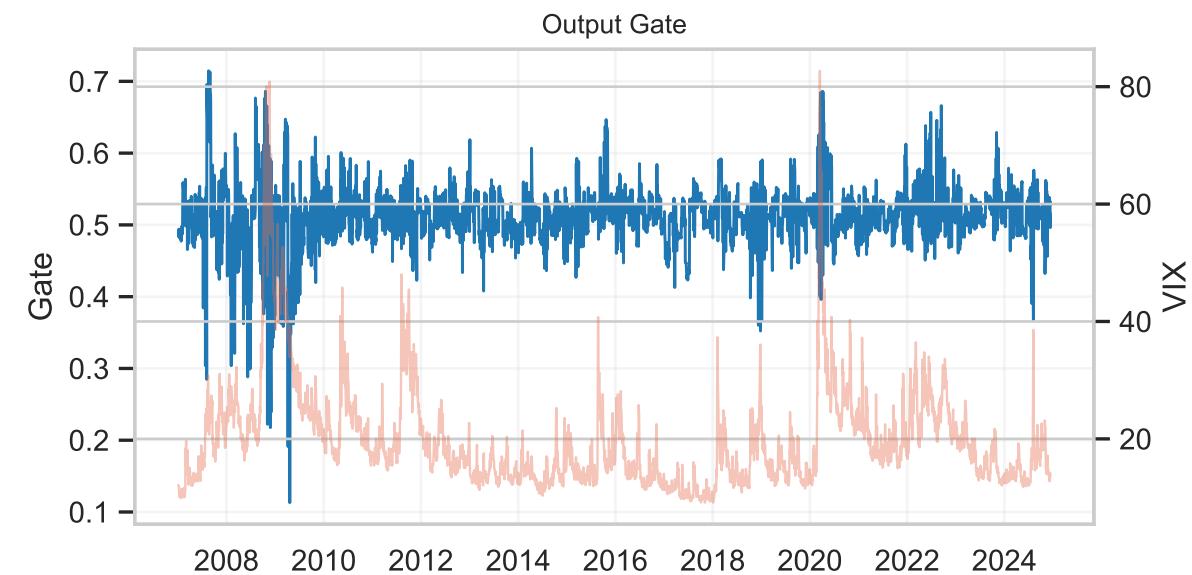
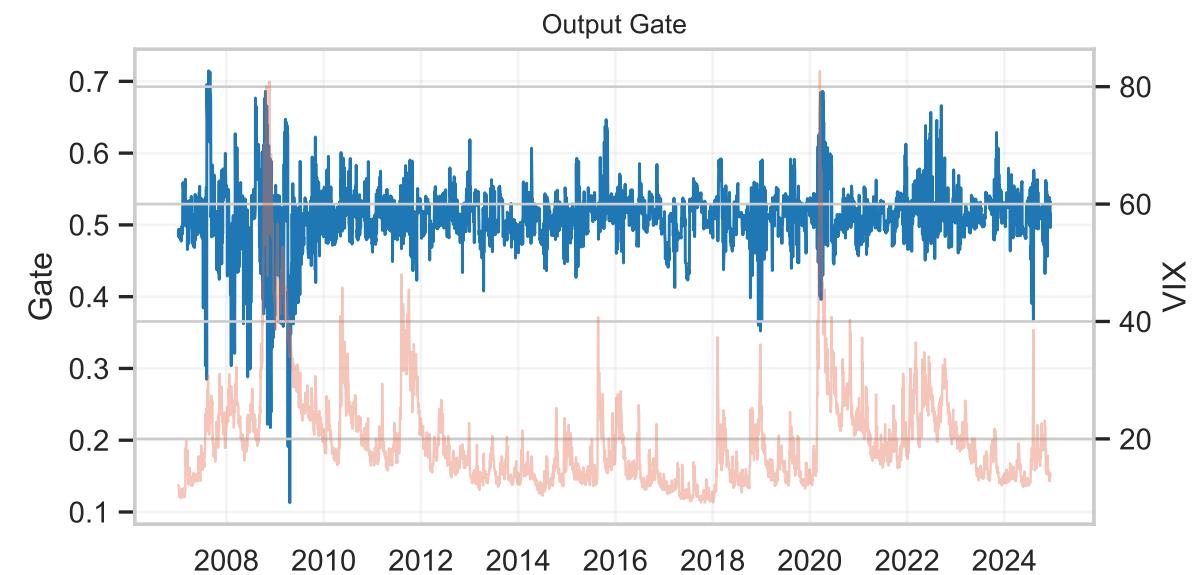
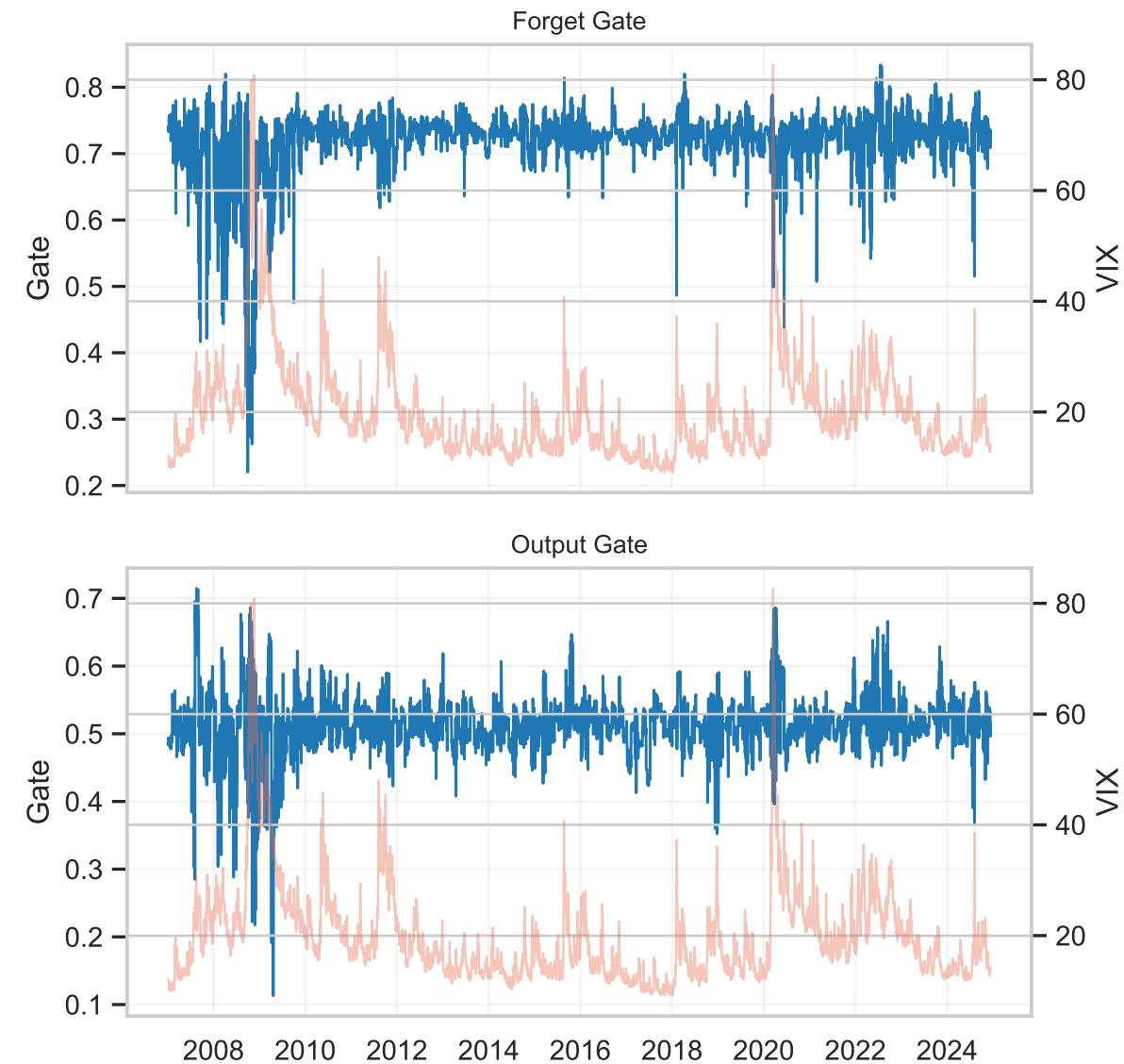
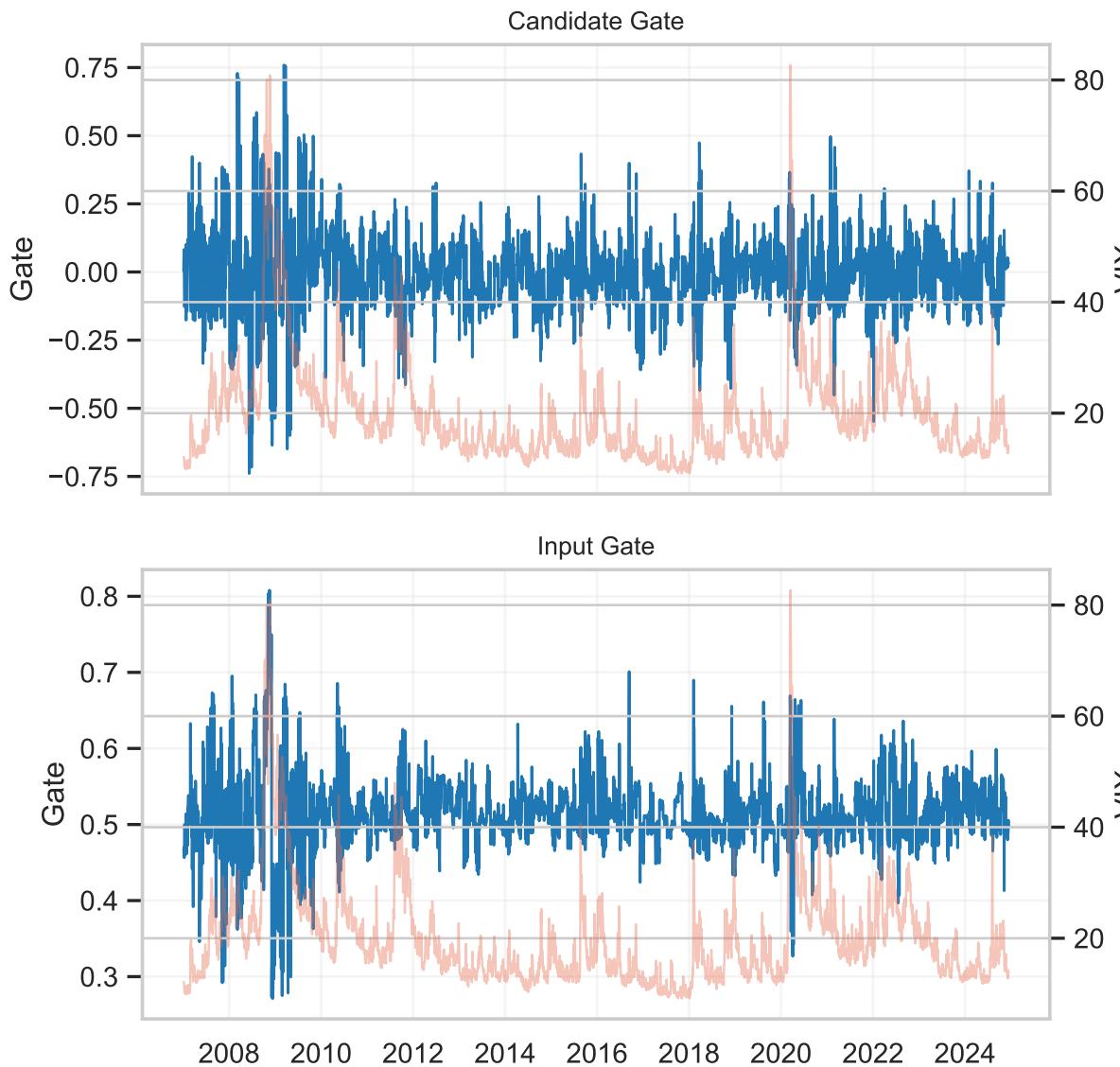
LSTM | Hybrid: Lag-1 Gate vs VIX



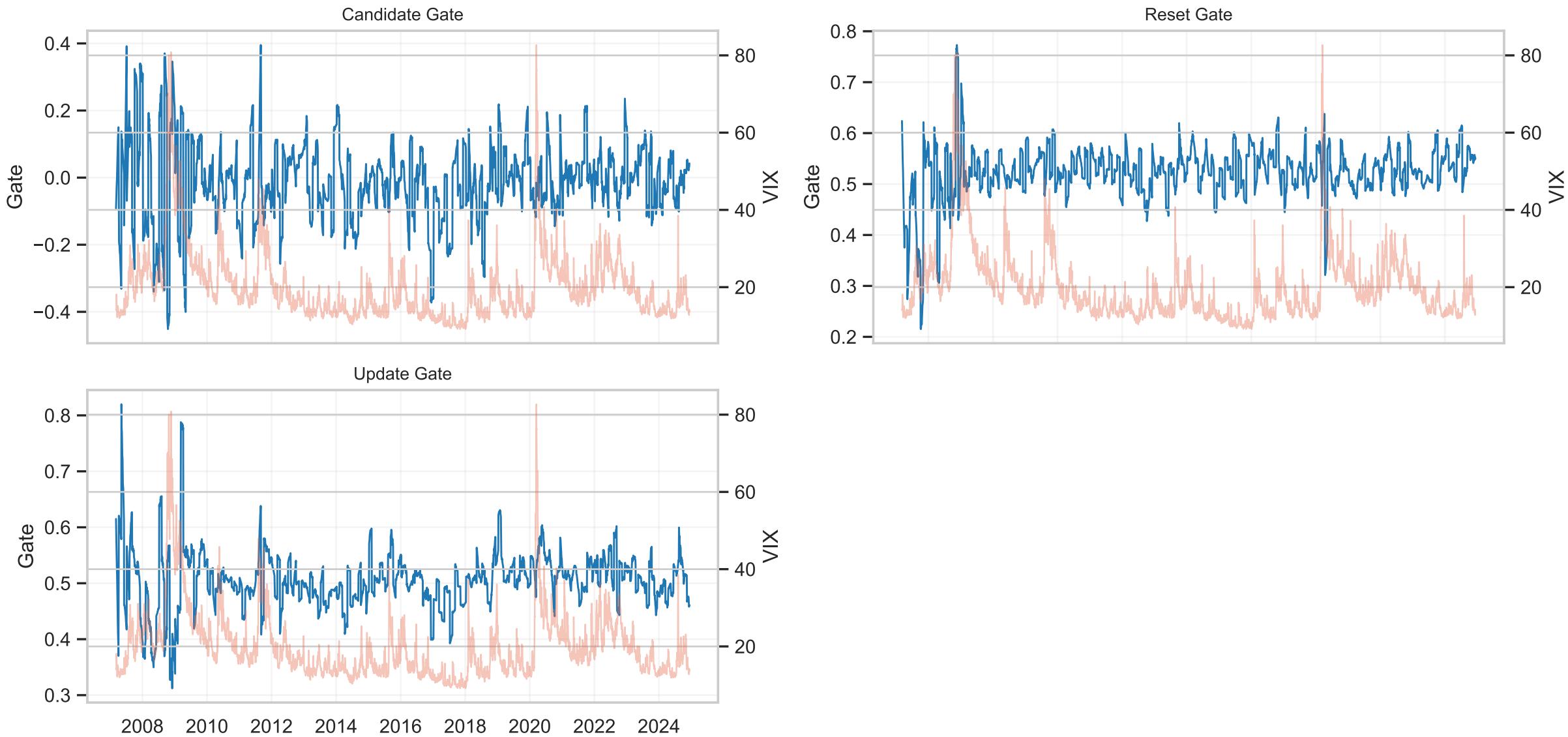
LSTM | Hybrid Residual: Lag-1 Gate vs VIX



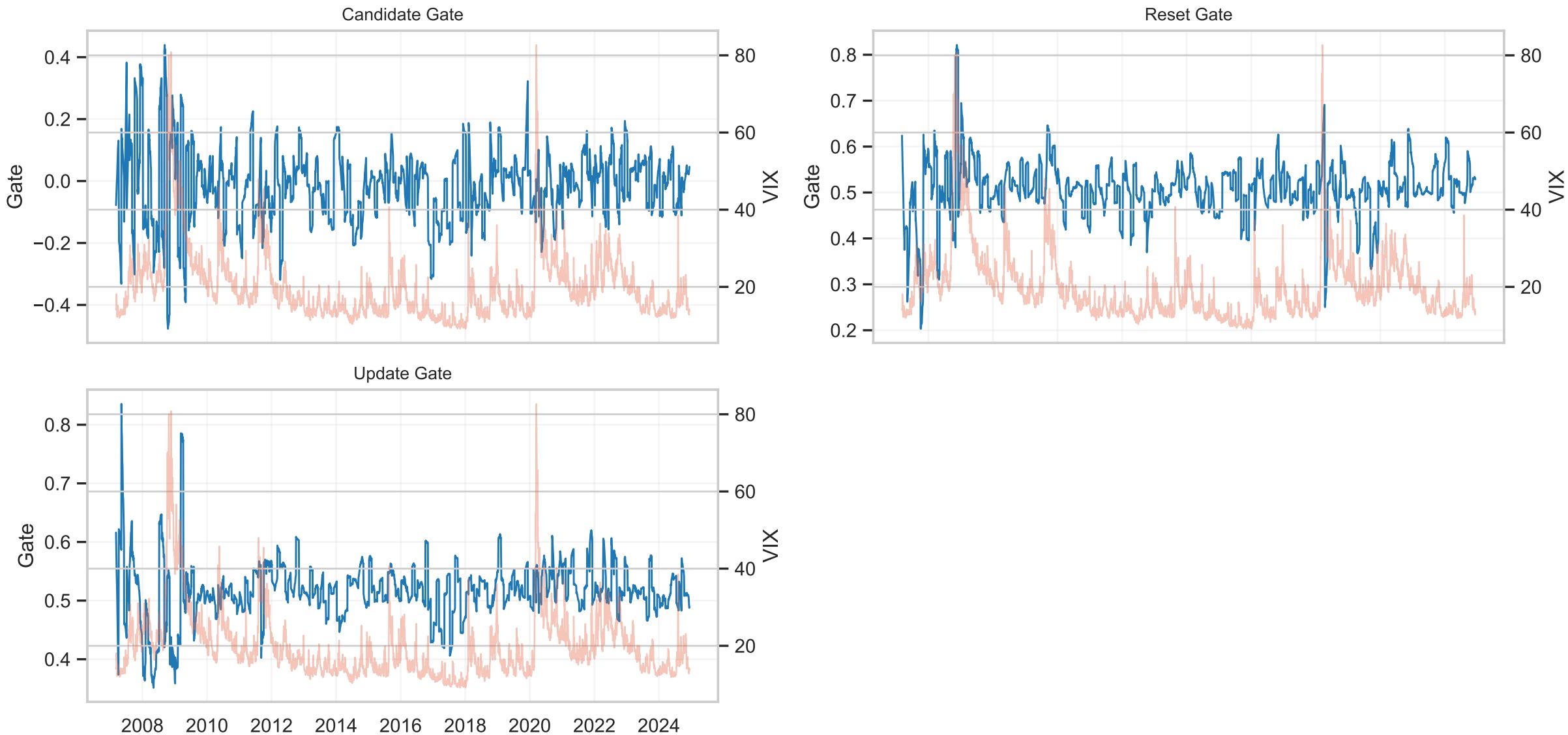
LSTM | Pure: Lag-1 Gate vs VIX



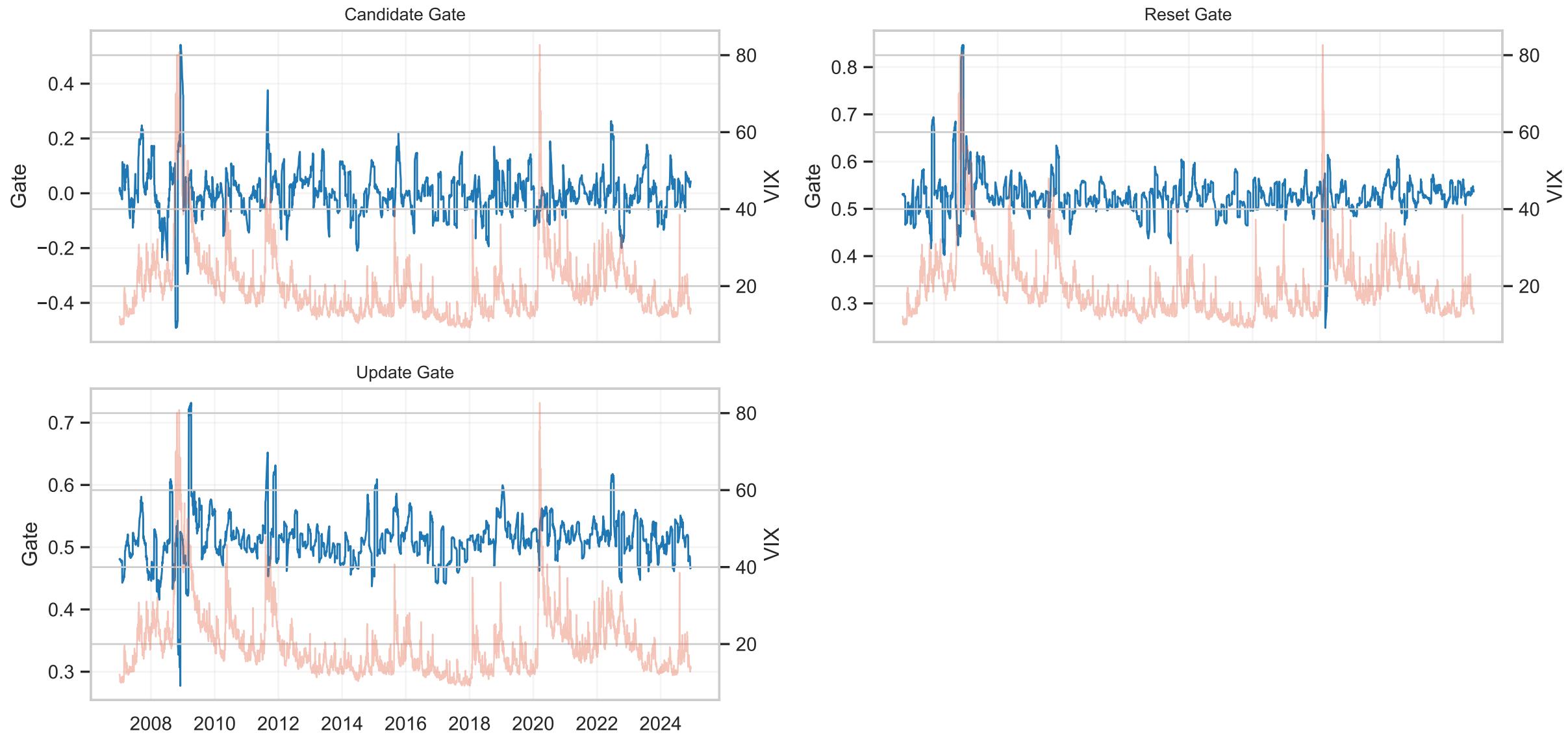
GRU | Hybrid: Mean Gate (Lags 1-20) vs VIX



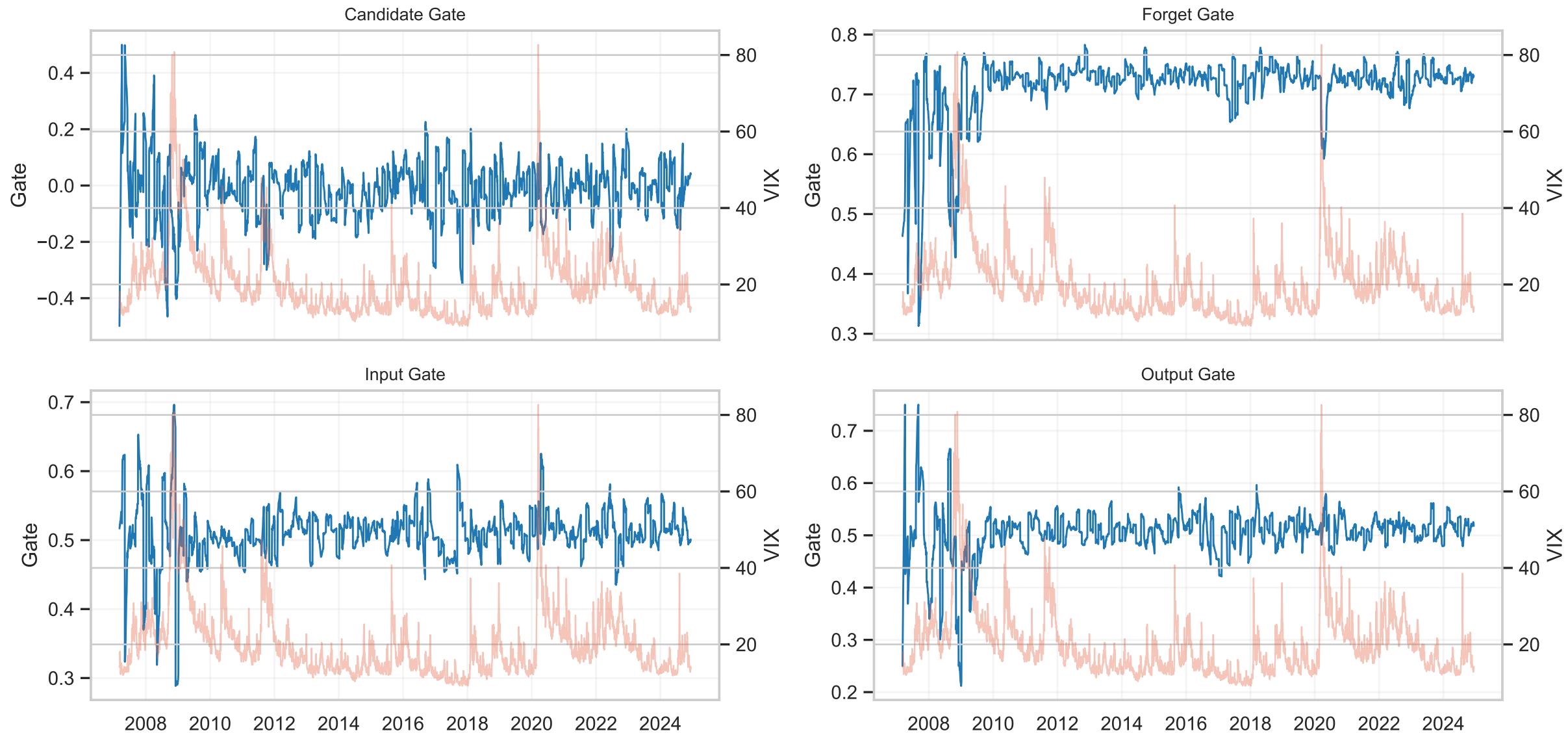
GRU | Hybrid Residual: Mean Gate (Lags 1-20) vs VIX



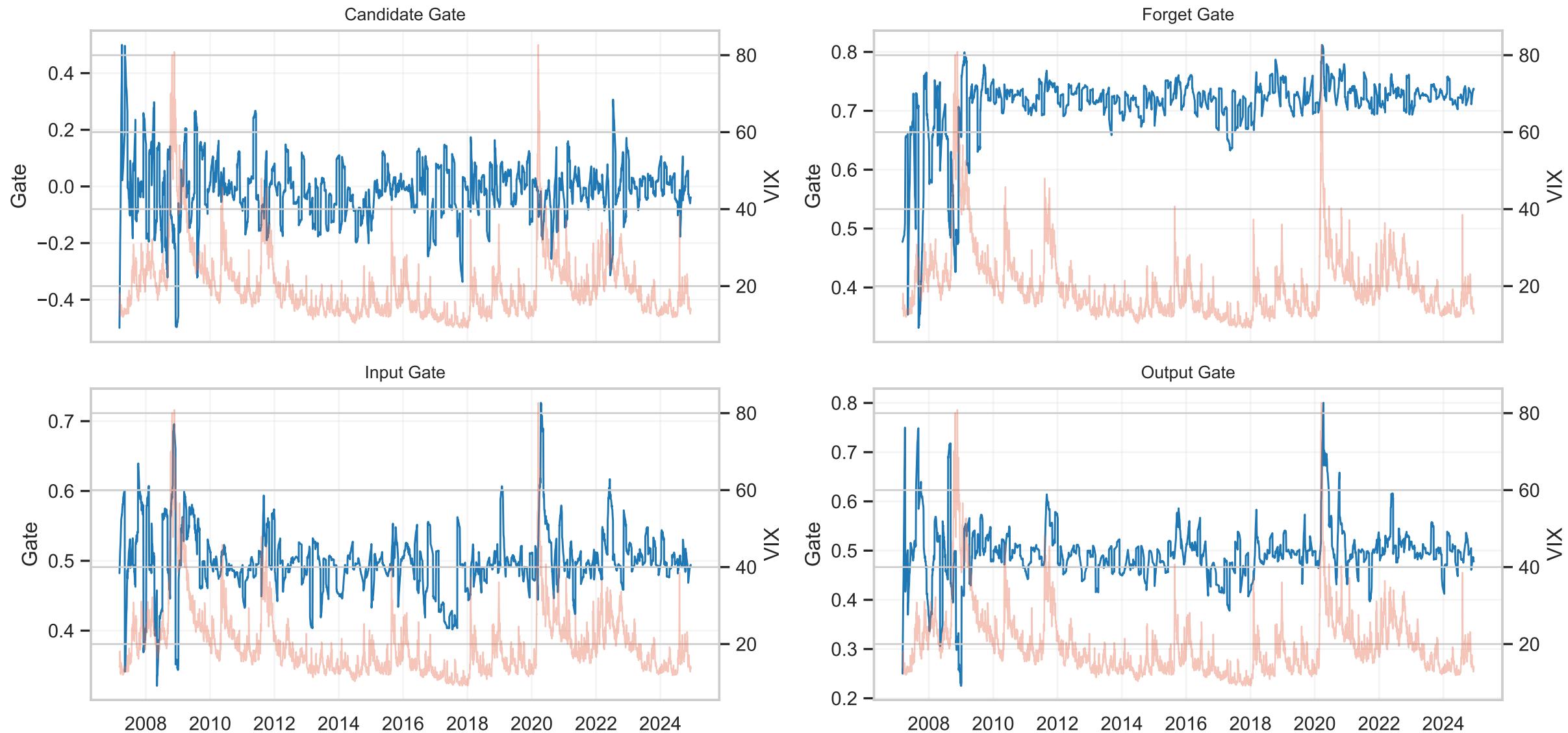
GRU | Pure: Mean Gate (Lags 1-20) vs VIX



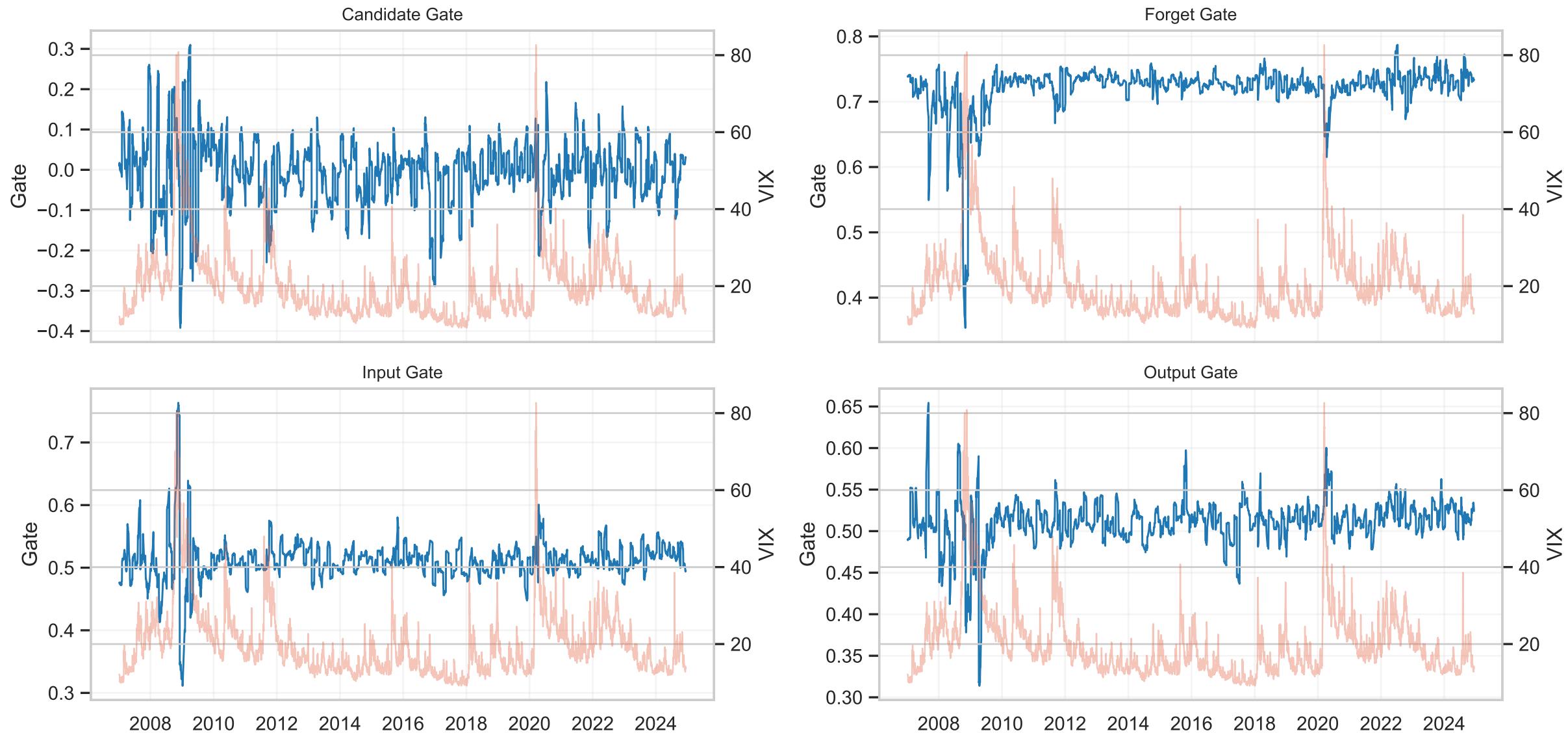
LSTM | Hybrid: Mean Gate (Lags 1-20) vs VIX



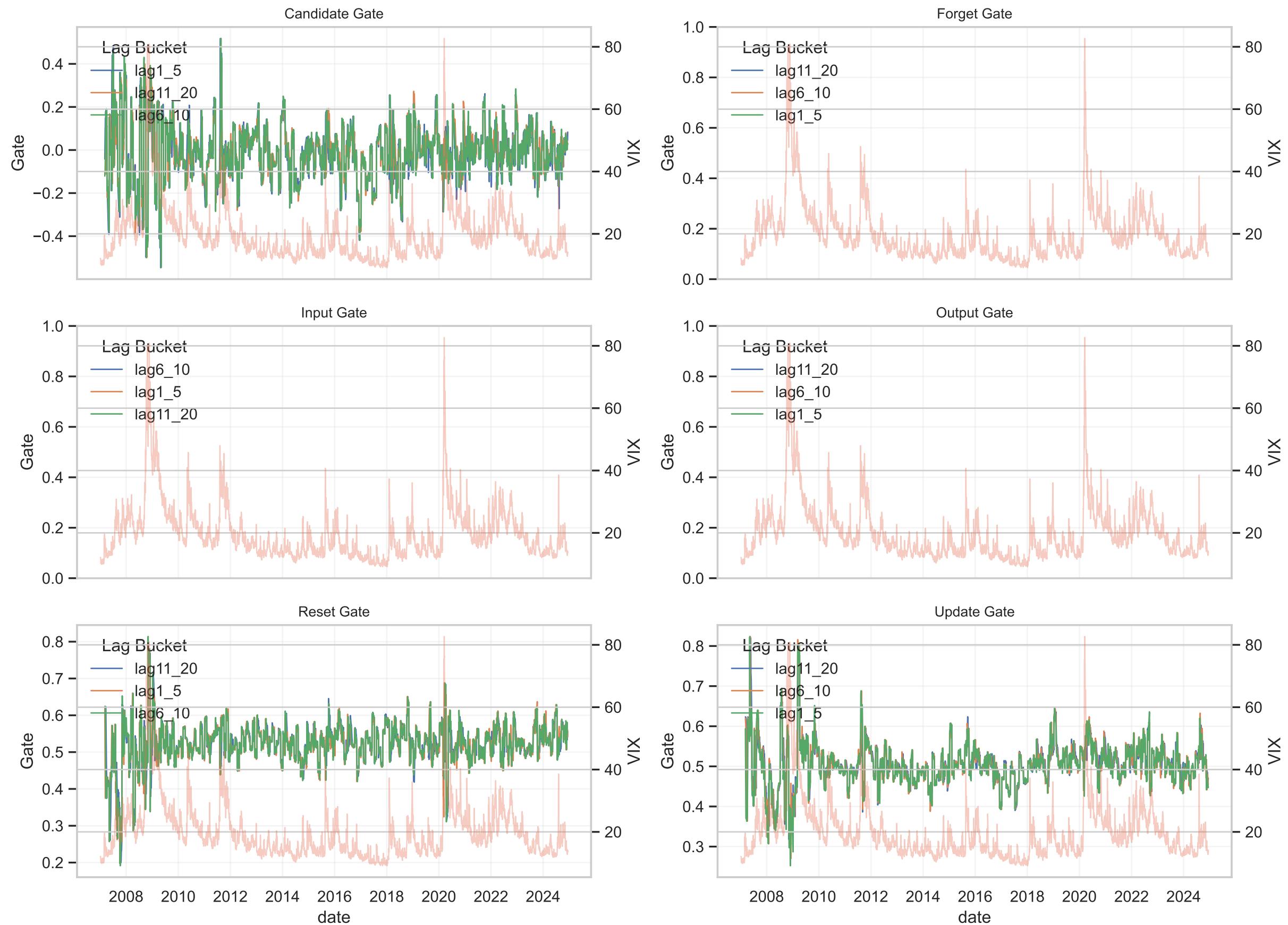
LSTM | Hybrid Residual: Mean Gate (Lags 1-20) vs VIX



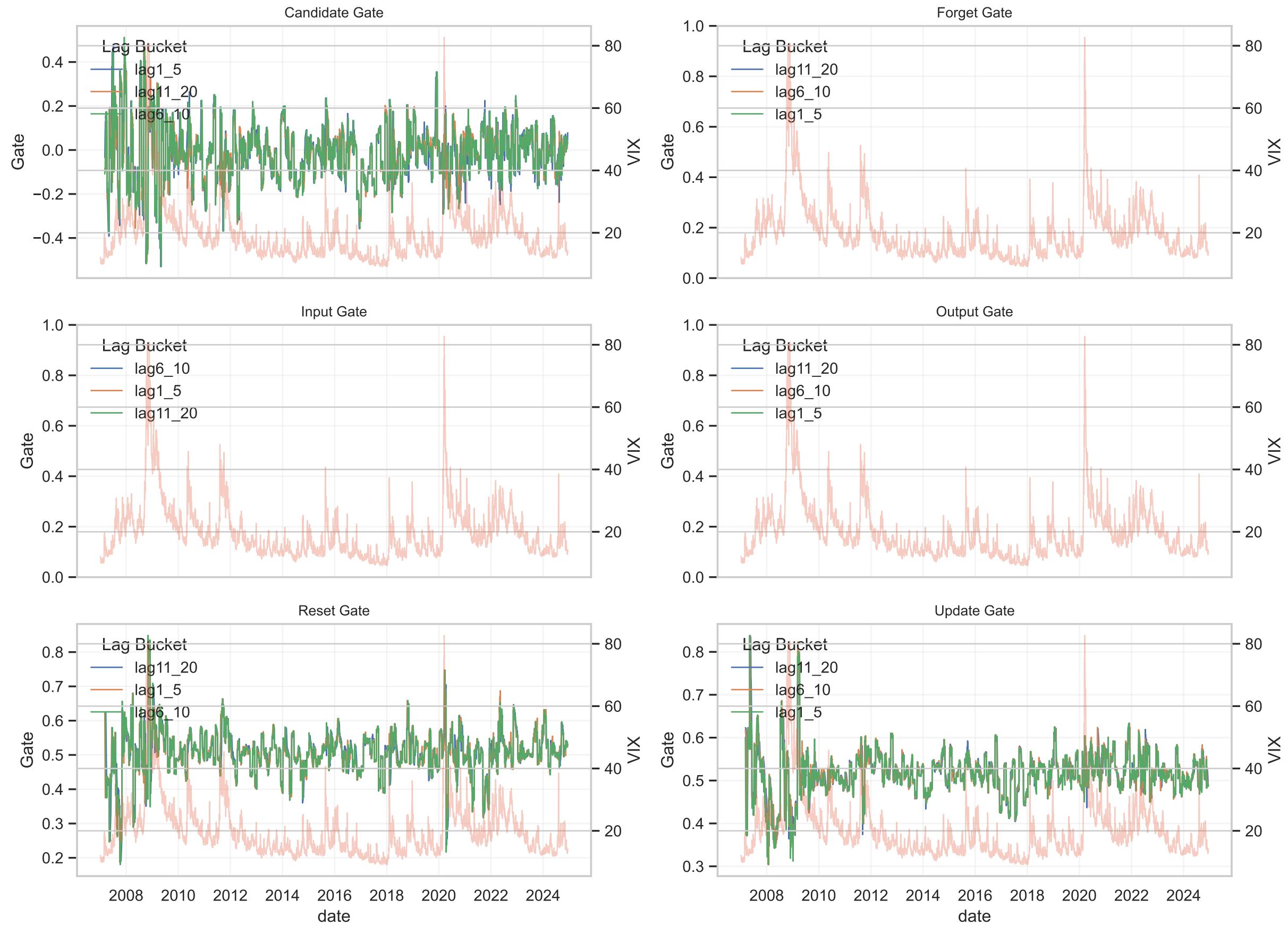
LSTM | Pure: Mean Gate (Lags 1-20) vs VIX



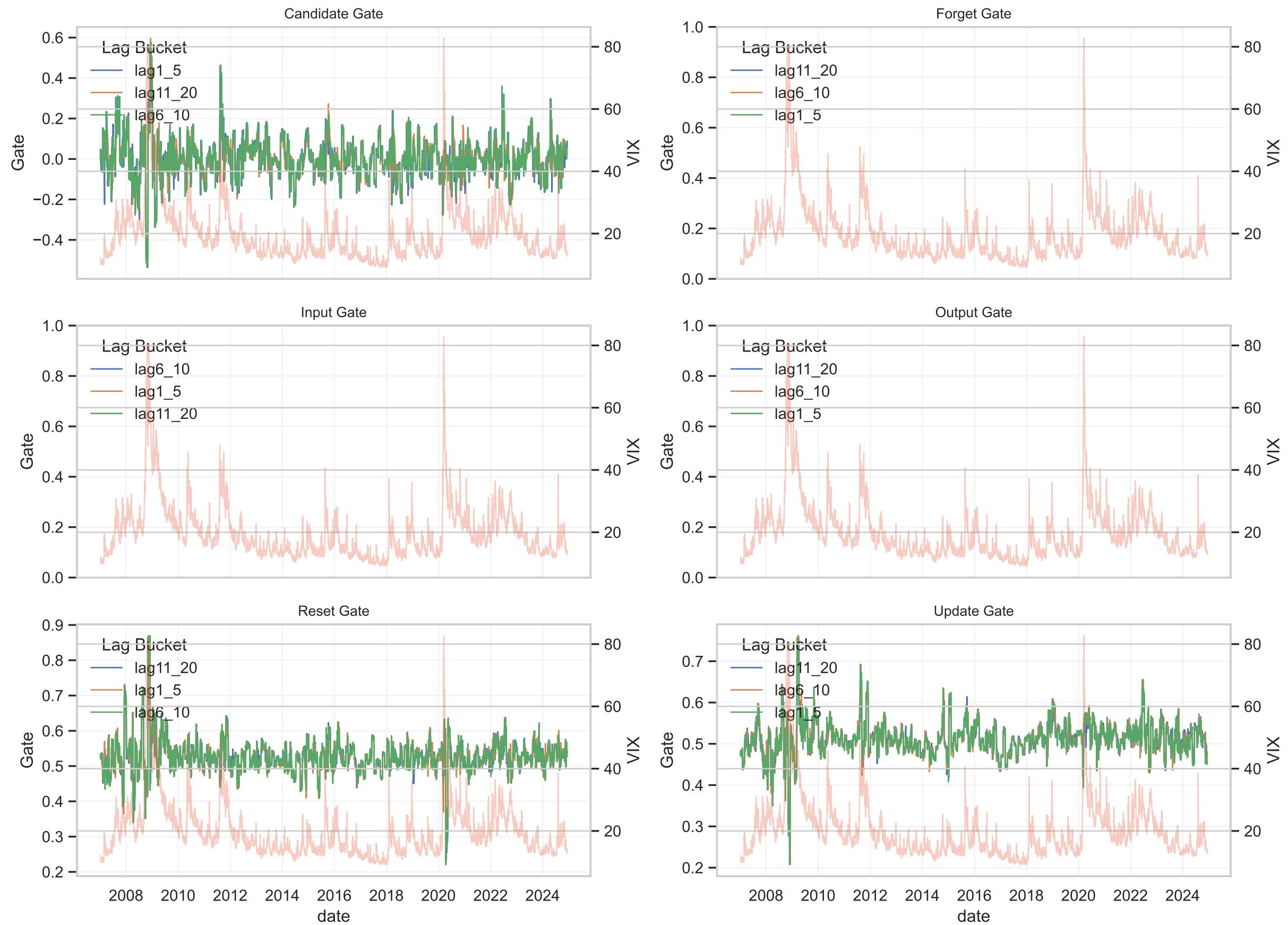
GRU | Hybrid: Lag-Bucket Gates vs VIX



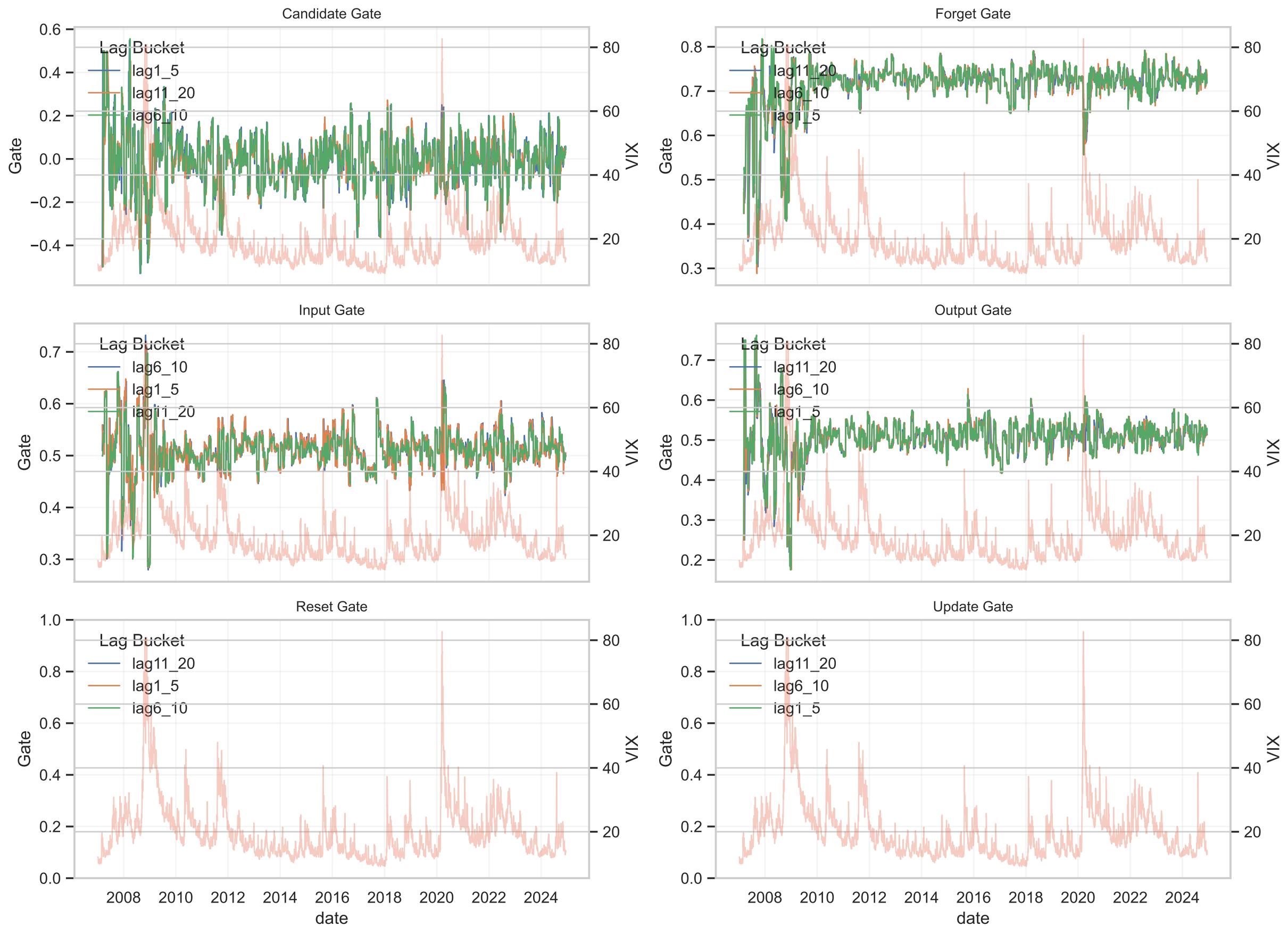
GRU | Hybrid Residual: Lag-Bucket Gates vs VIX



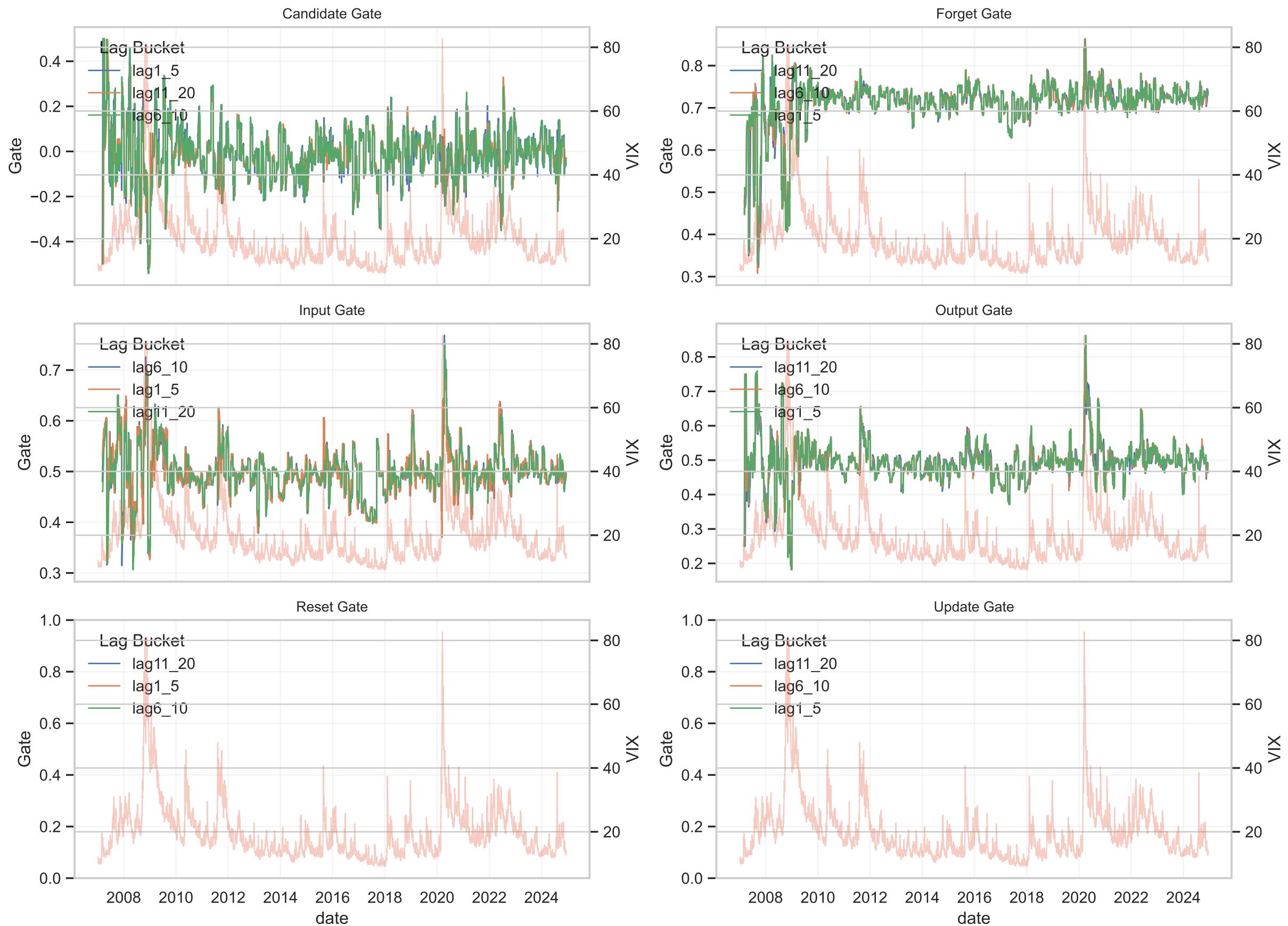
GRU | Pure: Lag-Bucket Gates vs VIX



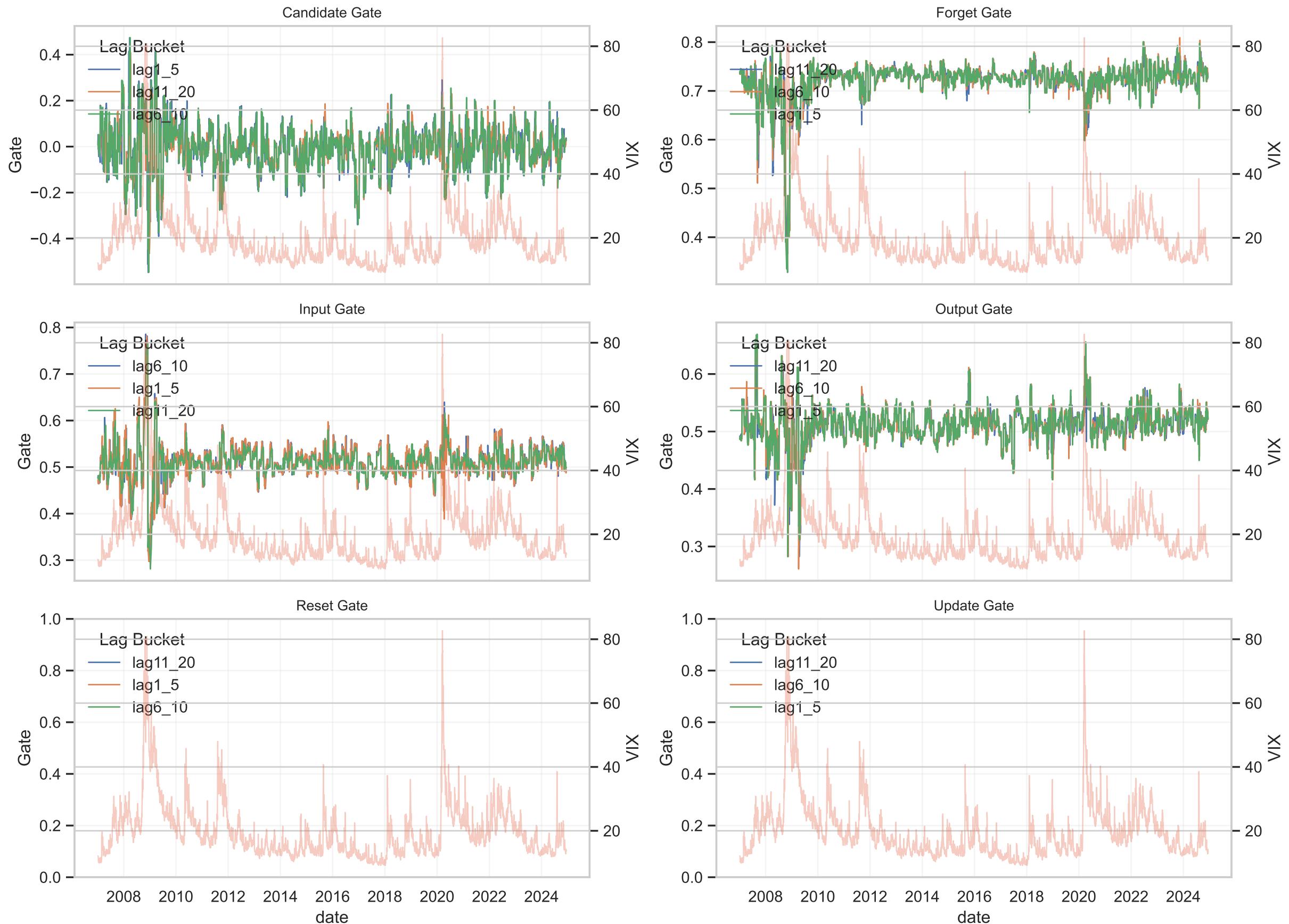
LSTM | Hybrid: Lag-Bucket Gates vs VIX



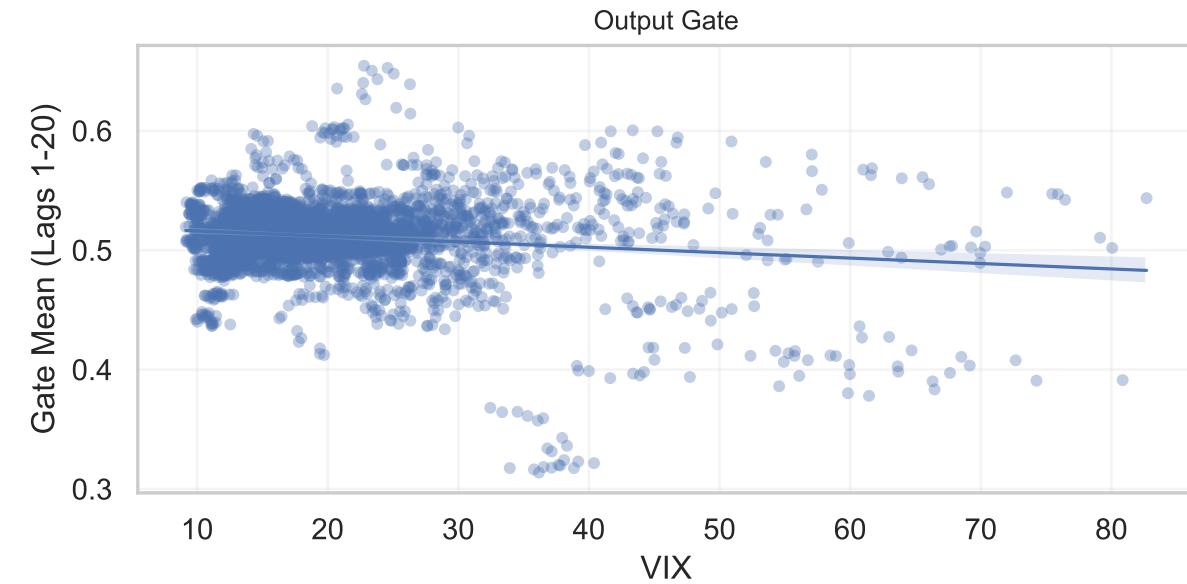
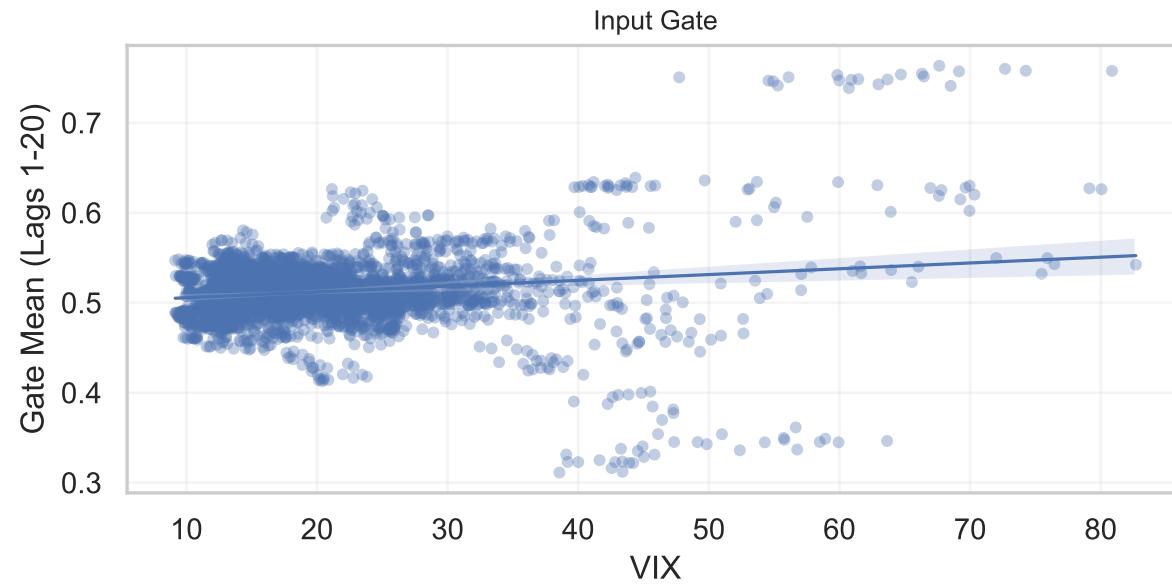
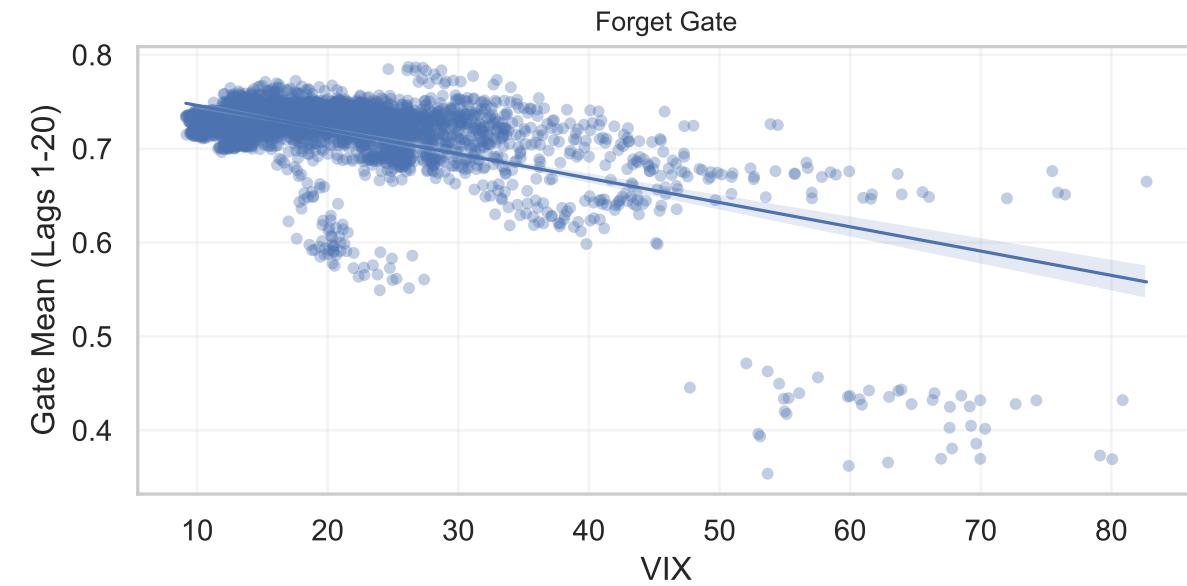
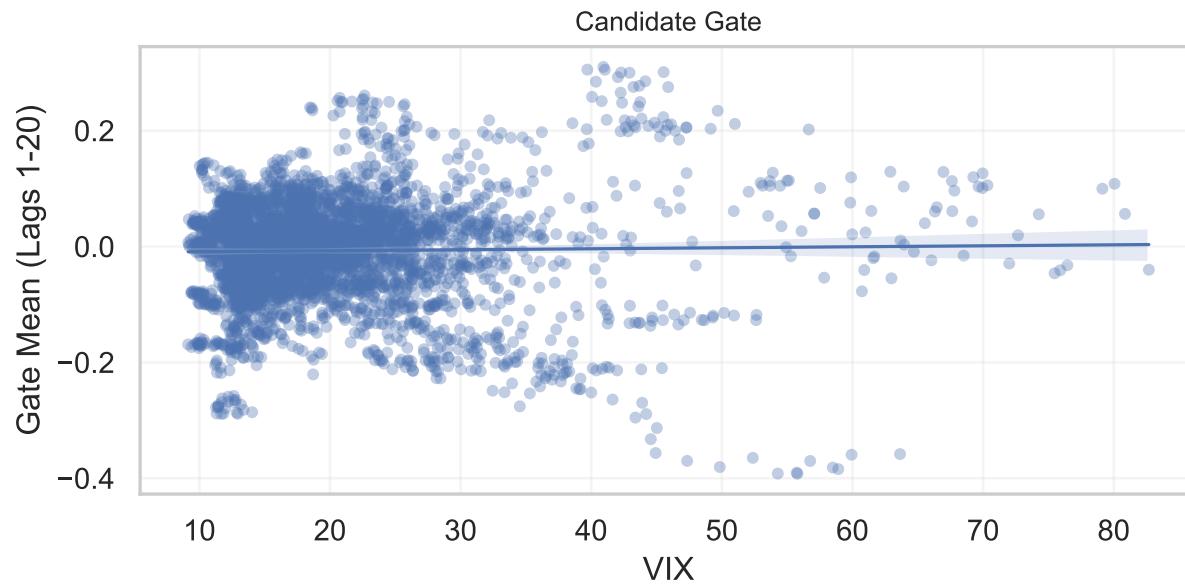
LSTM | Hybrid Residual: Lag-Bucket Gates vs VIX



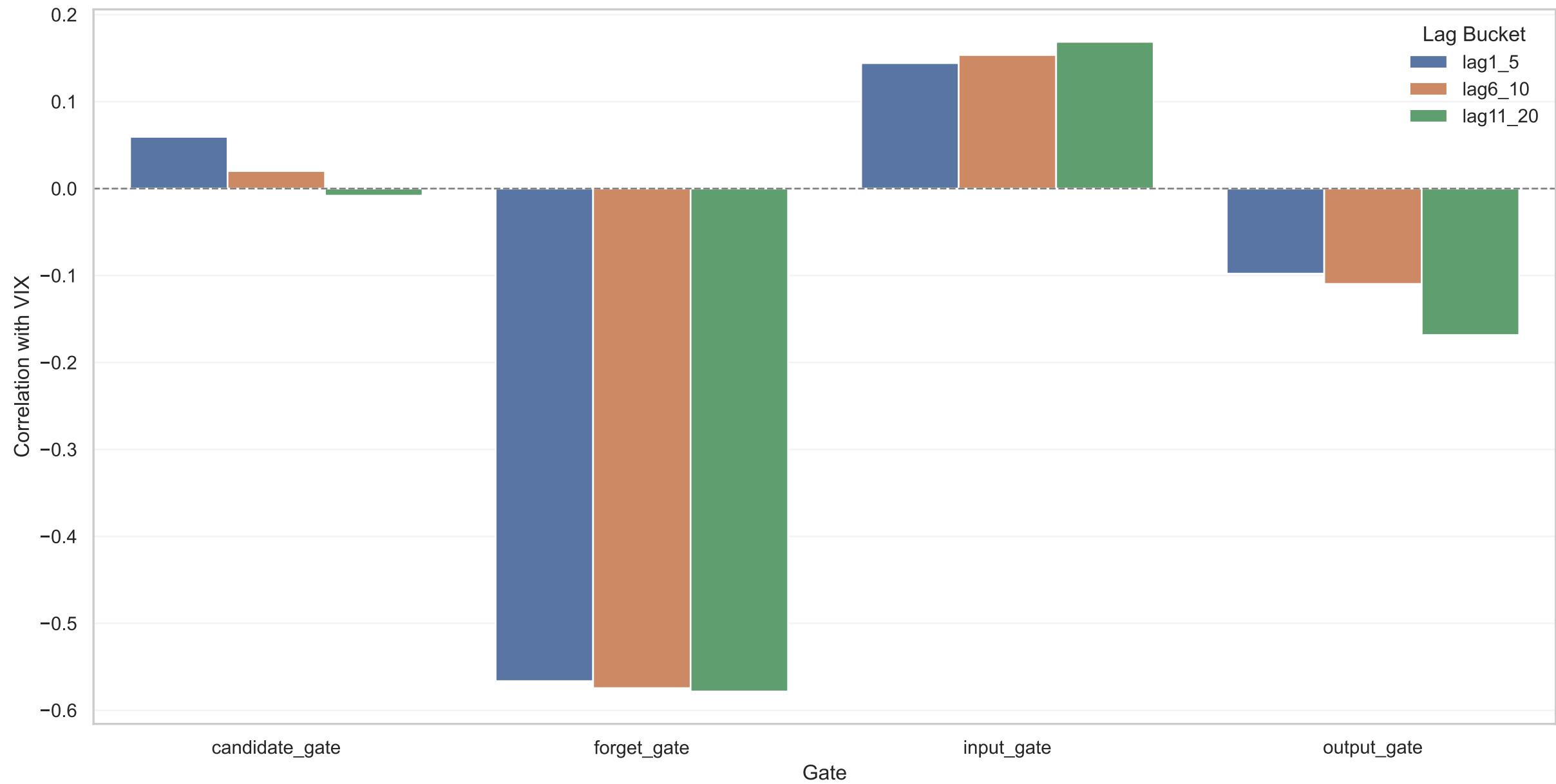
LSTM | Pure: Lag-Bucket Gates vs VIX



Pure LSTM: Mean Gate (Lags 1-20) vs VIX



Pure LSTM: Bucket-Level Gate-VIX Correlation (Pearson)



Coverage Notes

This PDF auto-generates all available report plots from CSV artifacts in reports/predictions.

If a section is missing, the corresponding source CSV was absent or empty.

Title formatting is standardized at the page level to avoid clipped or overlapping titles.